BINARY NUMBER SYSTEM

$N_{(2)}$

0 1

COUNTING

0,1,↓10,11,↓100, 101,
110,111,↓1000, ...

BREAKPOINTS ARE INDICATED BY ARROWS

POSITIONAL NOTATION DIAGRAM

POSITION OF DIGIT	10	9	8	7	6	5	4	3	2	1
POWERS OF TWO	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
DECIMAL VALUE	512	256	128	64	32	16	8	4	2	1

POSITIONAL NOTATION DIAGRAM

POSITION OF DIGIT	6	5	4	3	2	1
OCTAL POSITION	8^5	8^4	8^3	8^2	8^1	8^0
DECIMAL VALUE	32768	4096	512	64	8	1

OCTAL
ADDITION - SUBTRACTION

0	1	2	3	4	5	6	7
1	2	3	4	5	6	7	10
2	3	4	5	6	7	10	11
3	4	5	6	7	10	11	12
4	5	6	7	10	11	12	13
5	6	7	10	11	12	13	14
6	7	10	11	12	13	14	15
7	10	11	12	13	14	15	16

5243
+2267

OCTAL
MULTIPLICATION - DIVISION

$$\begin{array}{r} 56 \\ \times\ 7 \\ \hline \end{array}$$

0	1	2	3	4	5	6	7
1	1	2	3	4	5	6	7
2	2	4	6	10	12	14	16
3	3	6	11	14	17	22	25
4	4	10	14	20	24	30	34
5	5	12	17	24	31	36	43
6	6	14	22	30	36	44	52
7	7	16	25	34	43	52	61

POSITIONAL NOTATION DIAGRAM

POSITION OF DIGIT	5	4	3	2	1
HEXADECIMAL POSITION	16^4	16^3	16^2	16^1	16^0
DECIMAL VALUE	65536	4096	256	16	1

$$\begin{array}{r} 1\ B\ 2 \\ +F\ 9\ 8 \\ \hline \end{array}$$

HEXADECIMAL ADD - SUB MATRIX

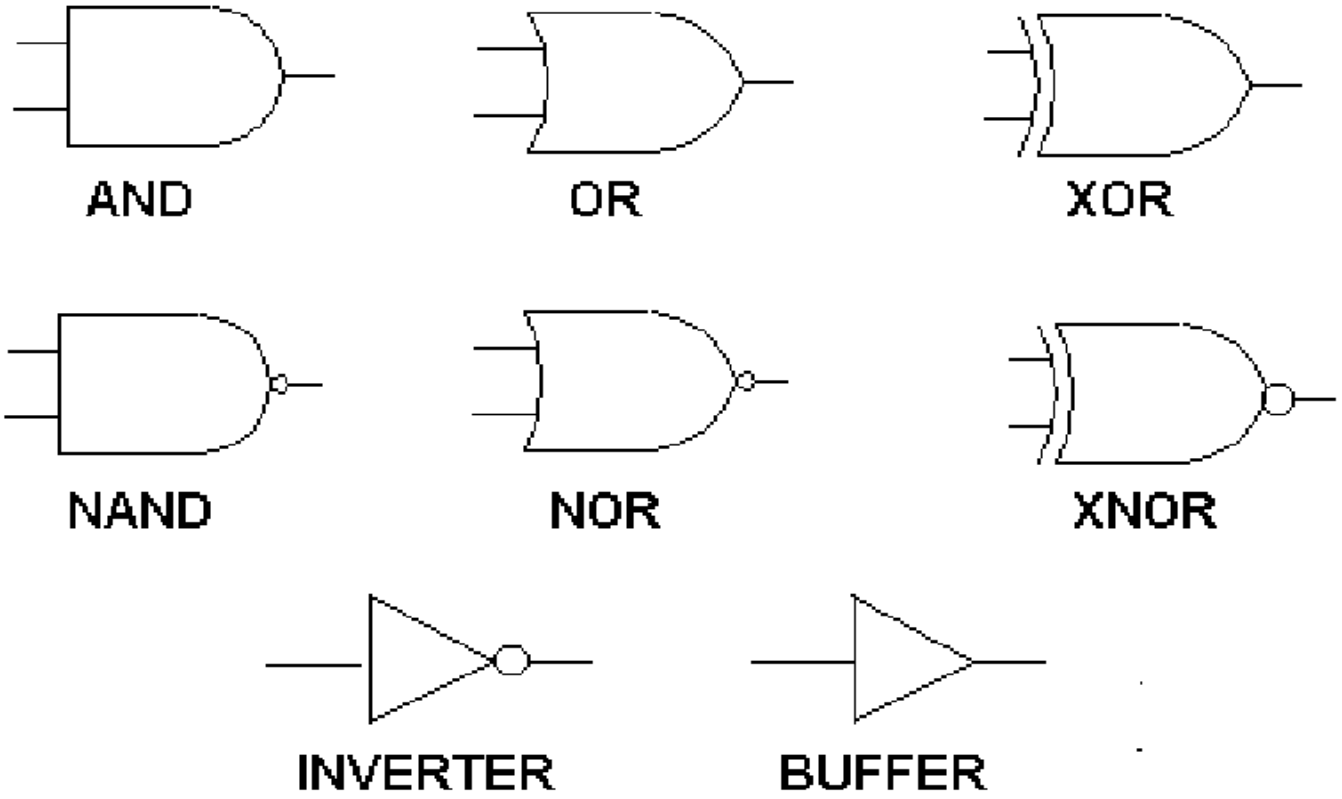
	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
1	2	3	4	5	6	7	8	9	A	B	C	D	E	F	10
2	3	4	5	6	7	8	9	A	B	C	D	E	F	10	11
3	4	5	6	7	8	9	A	B	C	D	E	F	10	11	12
4	5	6	7	8	9	A	B	C	D	E	F	10	11	12	13
5	6	7	8	9	A	B	C	D	E	F	10	11	12	13	14
6	7	8	9	A	B	C	D	E	F	10	11	12	13	14	15
7	8	9	A	B	C	D	E	F	10	11	12	13	14	15	16
8	9	A	B	C	D	E	F	10	11	12	13	14	15	16	17
9	A	B	C	D	E	F	10	11	12	13	14	15	16	17	18
A	B	C	D	E	F	10	11	12	13	14	15	16	17	18	19
B	C	D	E	F	10	11	12	13	14	15	16	17	18	19	1A
C	D	E	F	10	11	12	13	14	15	16	17	18	19	1A	1B
D	E	F	10	11	12	13	14	15	16	17	18	19	1A	1B	1C
E	F	10	11	12	13	14	15	16	17	18	19	1A	1B	1C	1D
F	10	11	12	13	14	15	16	17	18	19	1A	1B	1C	1D	1E

HEXADECIMAL MULTIPLICATION -

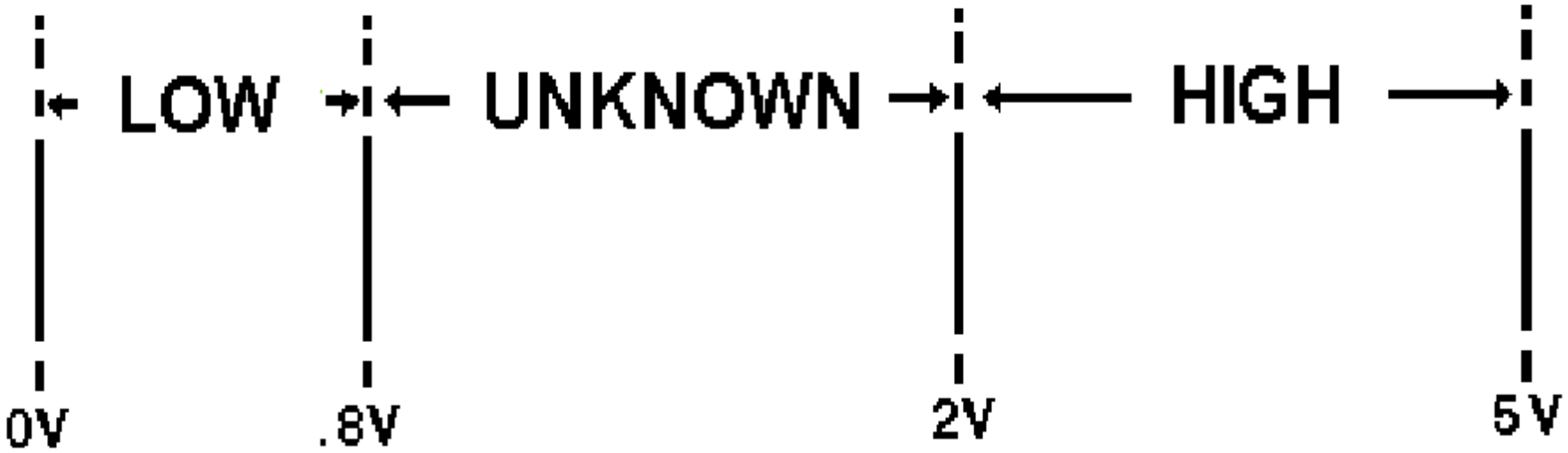
DIVISION MATRIX

	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
1	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
2	2	4	6	8	A	C	E	10	12	14	16	18	1A	1C	1E
3	3	6	9	C	F	12	15	18	1B	1E	21	24	27	2A	2D
4	4	8	C	10	14	18	1C	20	24	28	2C	30	34	38	3C
5	5	A	F	14	19	1E	23	28	2D	32	37	3C	41	46	4B
6	6	C	12	18	1E	24	2A	30	36	3C	42	48	4E	54	5A
7	7	E	15	1C	23	2A	31	38	3F	46	4D	54	5B	62	69
8	8	10	18	20	28	30	38	40	48	50	58	60	68	70	78
9	9	12	1B	24	2D	36	3F	48	51	5A	63	6C	75	7E	87
A	A	14	1E	28	32	3C	46	50	5A	64	6E	78	82	8C	96
B	B	16	21	2C	37	42	4D	58	63	6E	79	84	8F	9A	A5
C	C	18	24	30	3C	48	54	60	6C	78	84	90	9C	A8	B4
D	D	1A	27	34	41	4E	5B	68	75	82	8F	9C	A9	B6	C3
E	E	1C	2A	38	46	54	62	70	7E	8C	9A	A8	B6	C4	D2
F	F	1E	2D	3C	4B	5A	69	78	87	96	A5	B4	C3	D2	E1

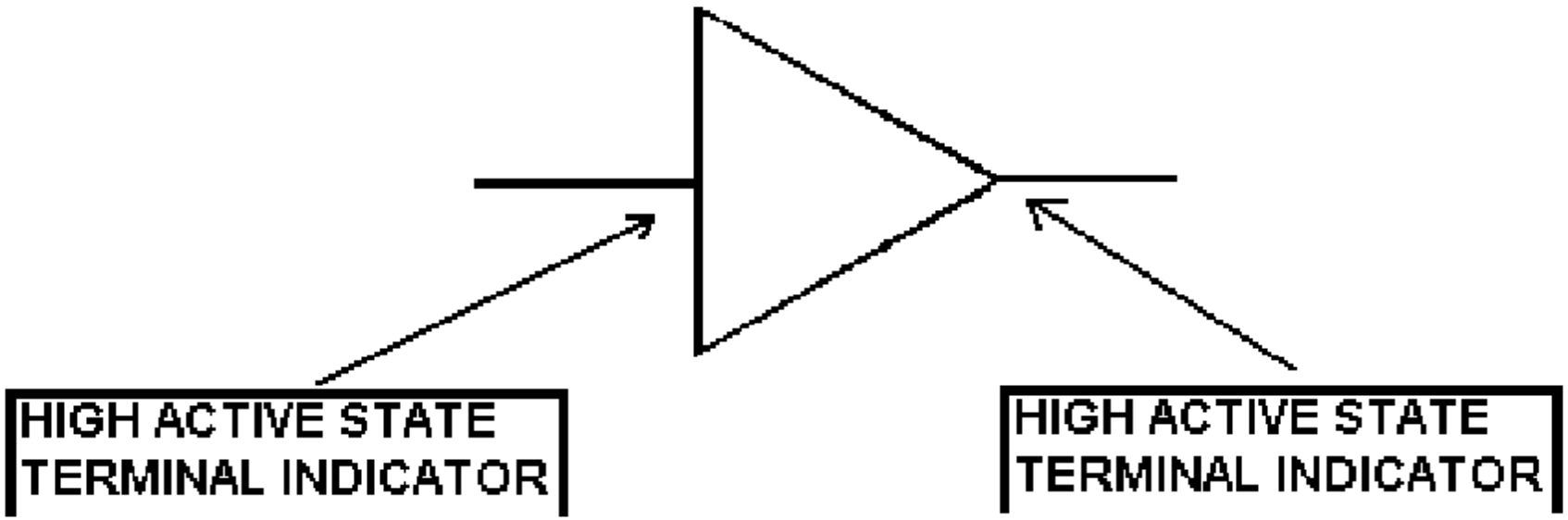
```
  4CE
X   E
-----
```



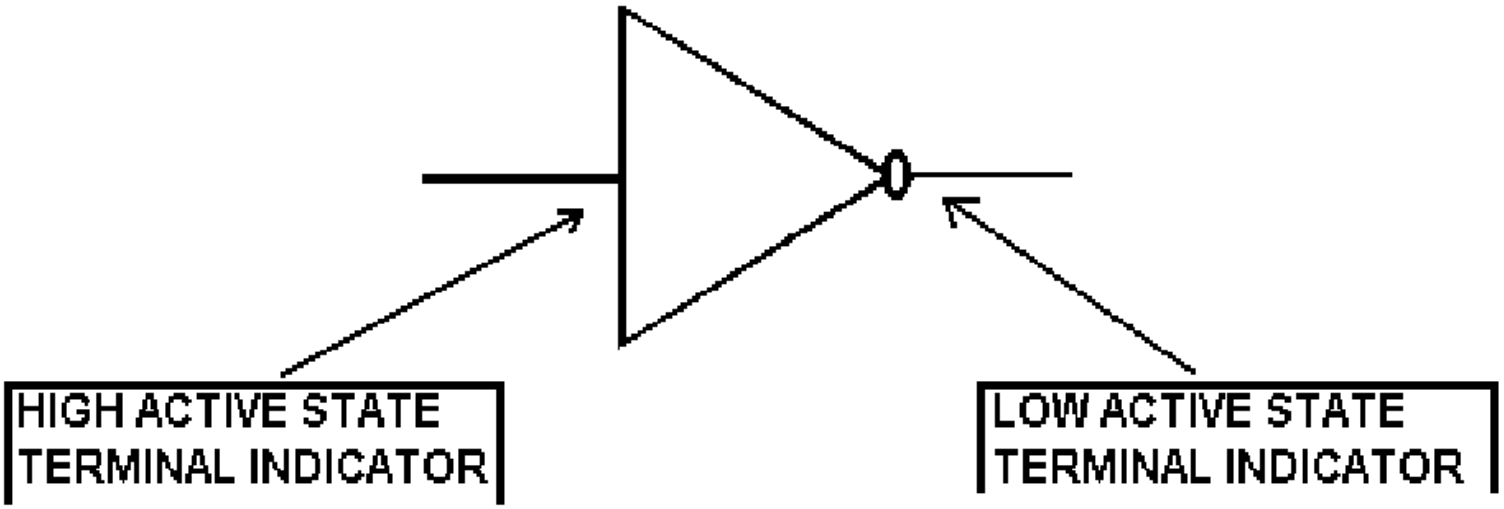
Integrated Circuit Logic Gates



THRESHOLD VOLTAGES FOR TTL INTEGRATED CIRCUITS



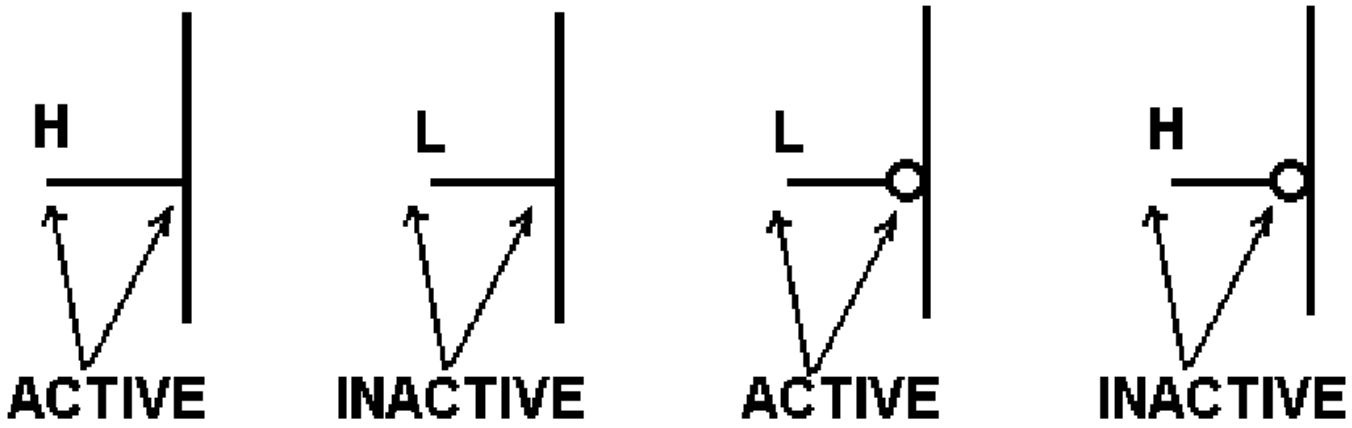
BUFFER SYMBOL & TERMINAL INDICATORS

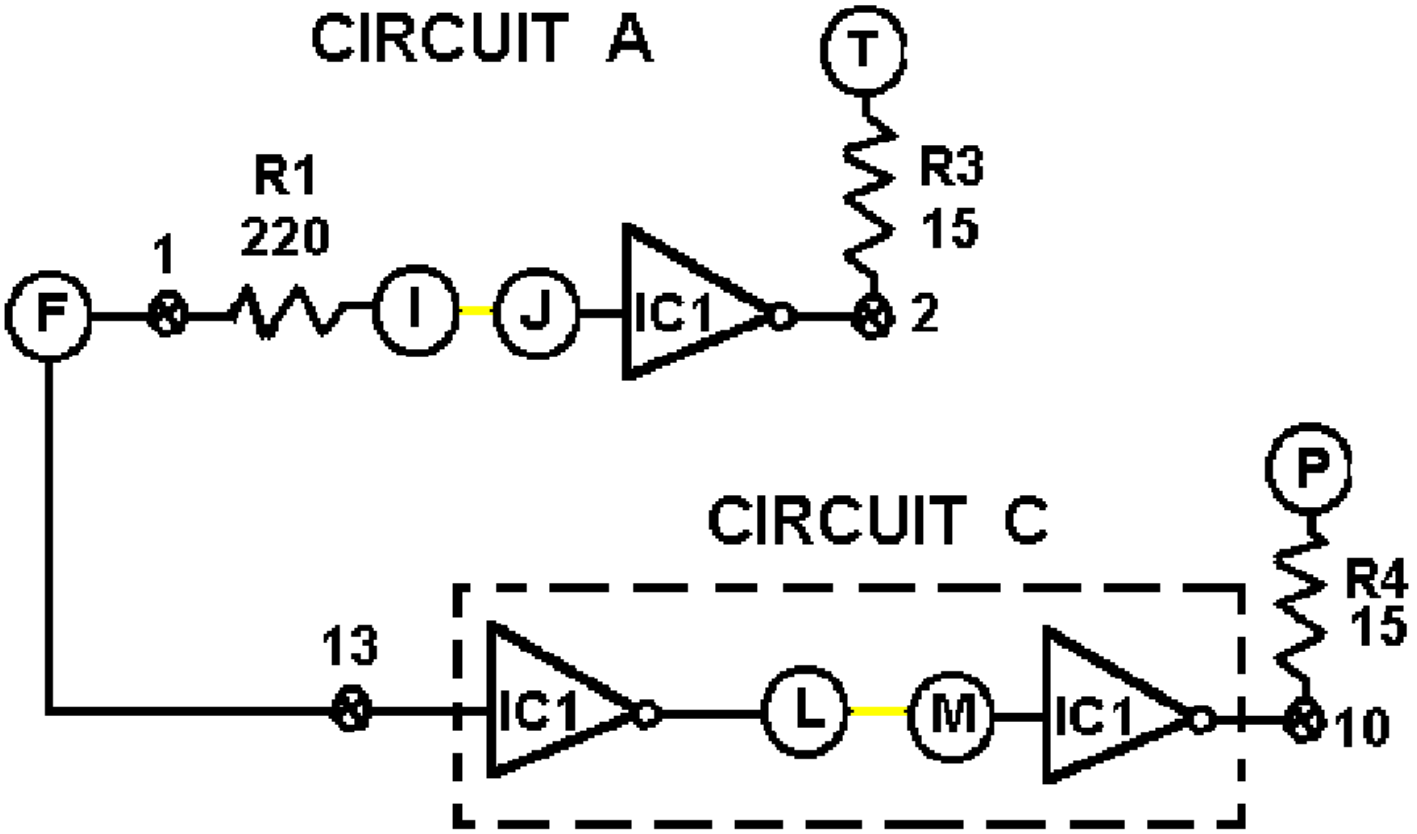


Inverter Symbol and Terminal Indicators

ACTIVE - VOLTAGE IS THE SAME AS THE TERMINAL INDICATOR.

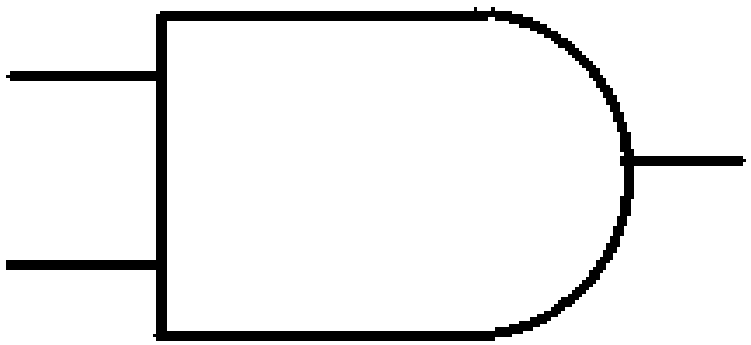
INACTIVE - VOLTAGE IS OPPOSITE FROM THE TERMINAL INDICATOR.



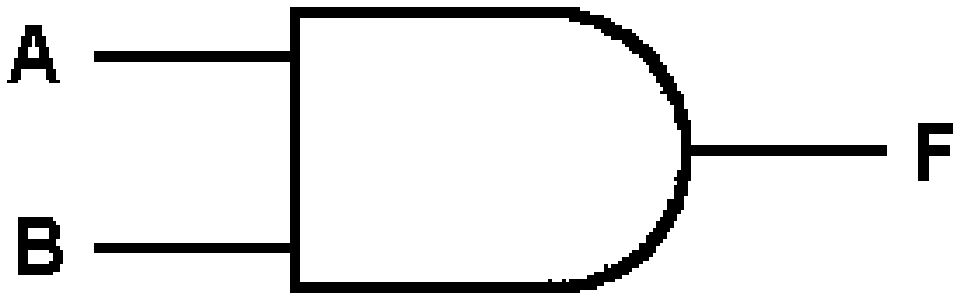


PC130-106

EL05-S36



AND gate logic symbol

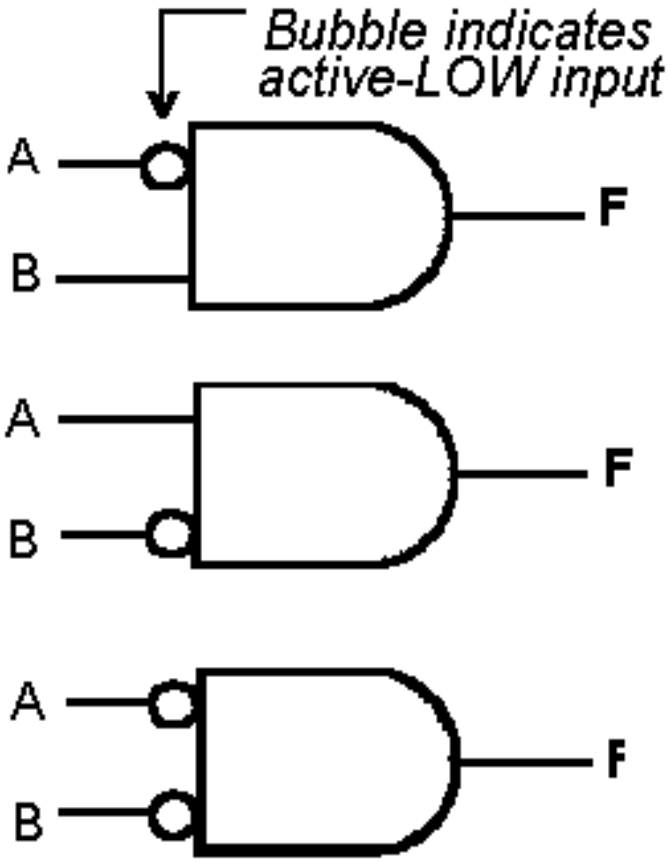


$$A \bullet B = F$$

$$[\ AB = F\ ]$$

Logic Expression for AND gate

4-200-10



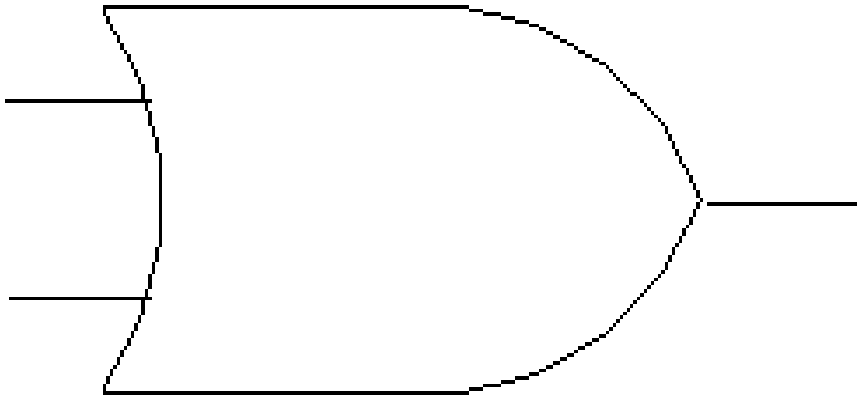
AND VARIATIONS

A	B	F
0	0	
0	1	
1	0	
1	1	

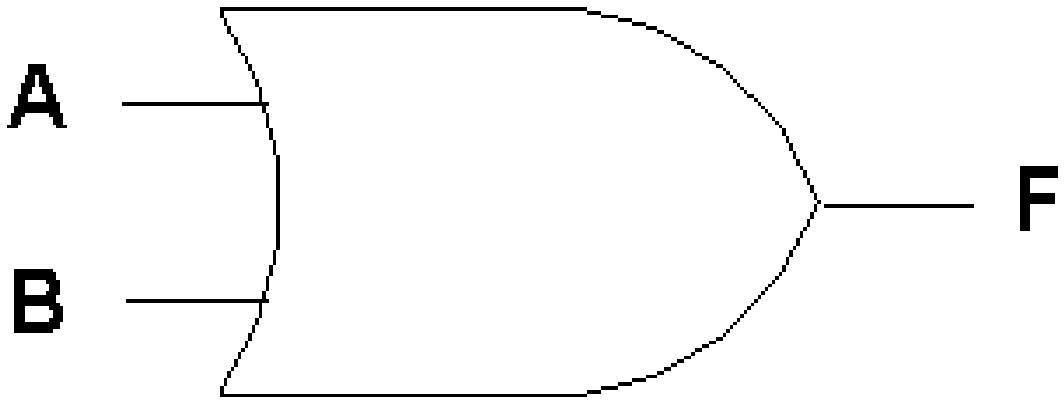
A	B	F
0	0	
0	1	
1	0	
1	1	

A	B	F
0	0	
0	1	
1	0	
1	1	

4-200-08

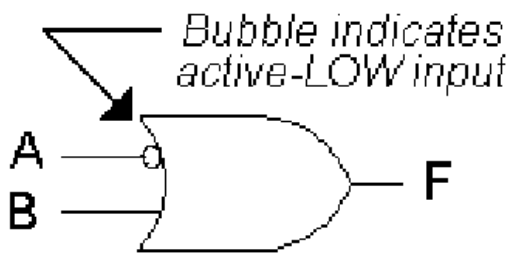


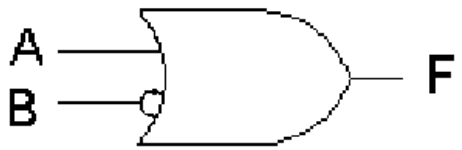
OR gate logic symbol

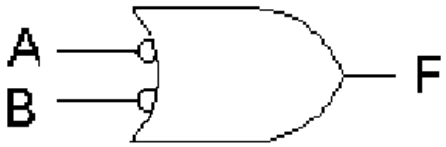


$$A + B = F$$

Logic Expression for OR gate





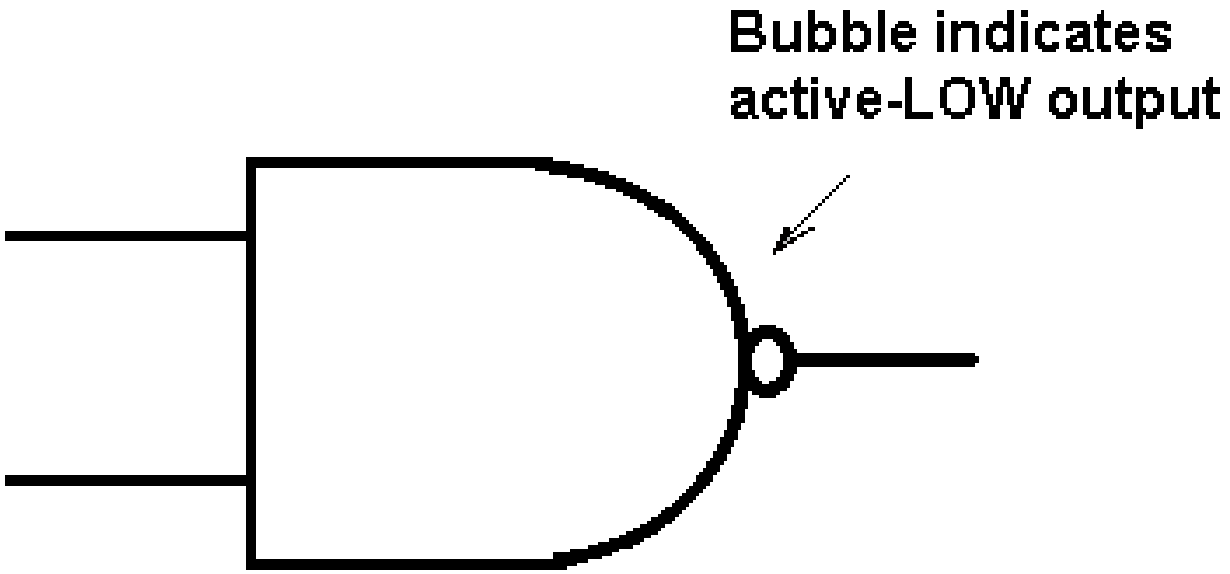


OR VARIATIONS

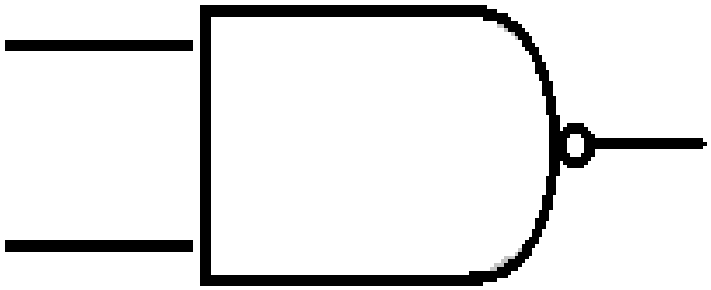
A	B	F
0	0	
0	1	
1	0	
1	1	

A	B	F
0	0	
0	1	
1	0	
1	1	

A	B	F
0	0	
0	1	
1	0	
1	1	



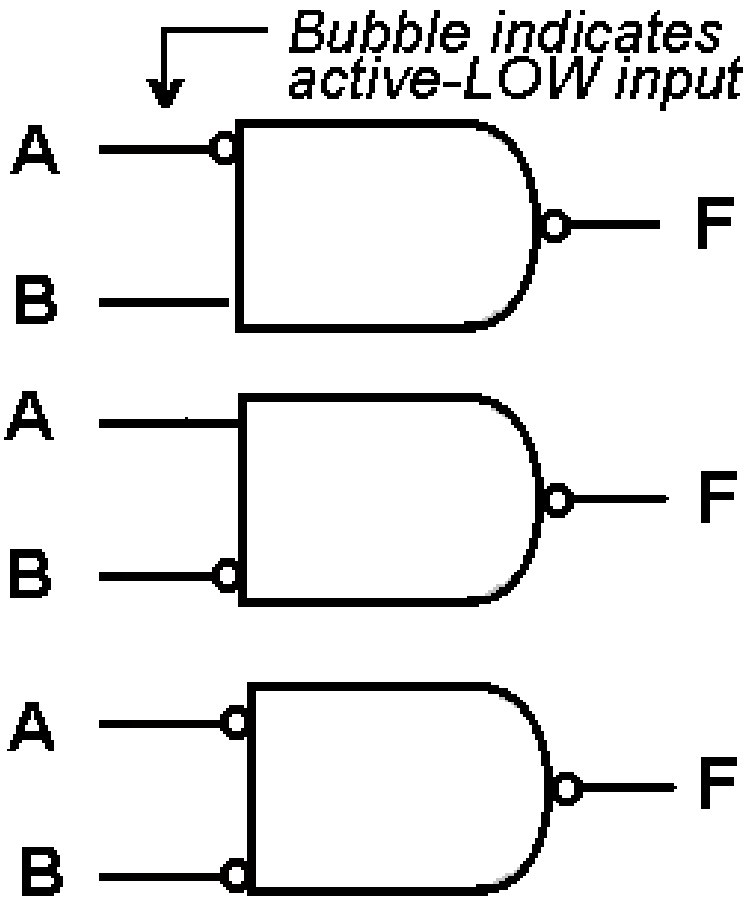
NAND gate symbol



$$A \cdot B = \overline{F}$$

$$\overline{AB} = F$$

Logic Expression for NAND gate



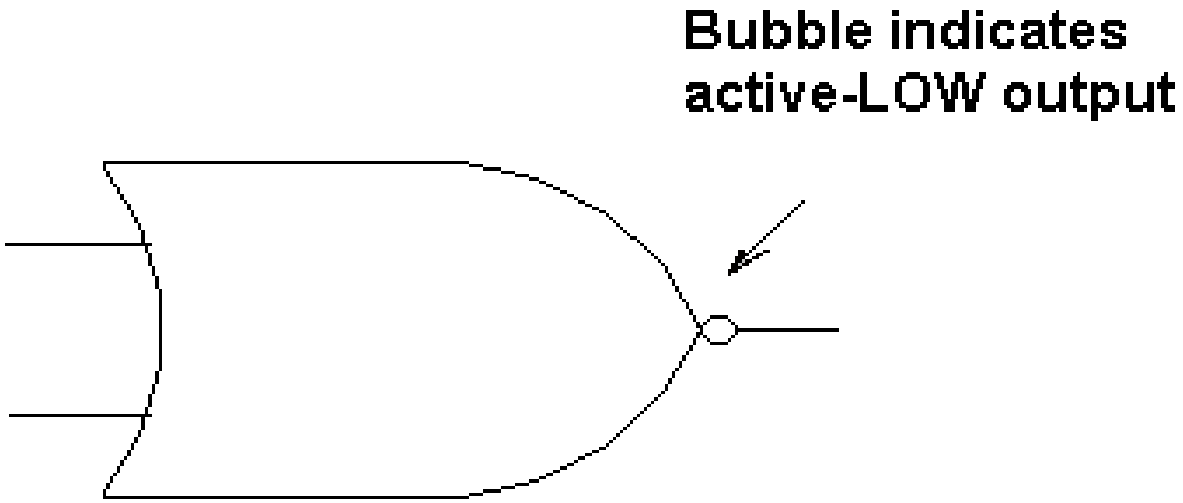
NAND VARIATIONS

A	B	F
0	0	
0	1	
1	0	
1	1	

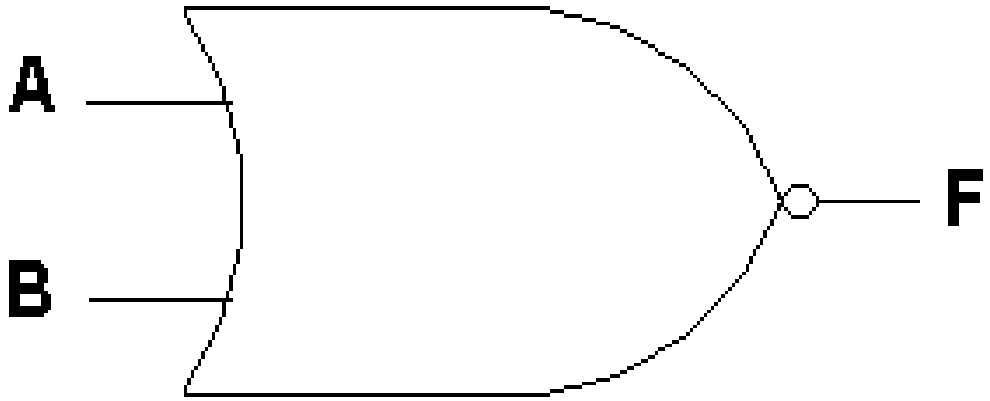
A	B	F
0	0	
0	1	
1	0	
1	1	

A	B	F
0	0	
0	1	
1	0	
1	1	

4-200-39



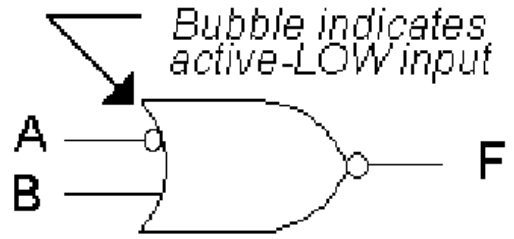
NOR gate logic symbol

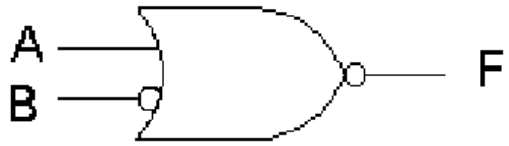


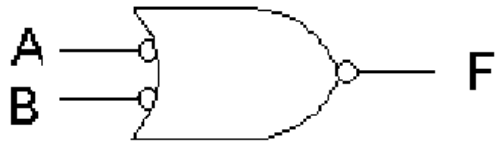
$$A + B = \overline{F}$$

$$\overline{A + B} = F$$

Logic Expression for NOR gate





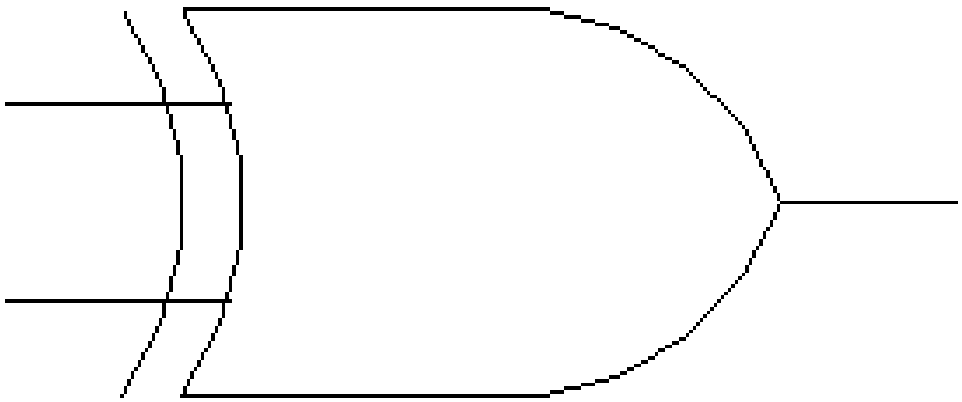


NOR VARIATIONS

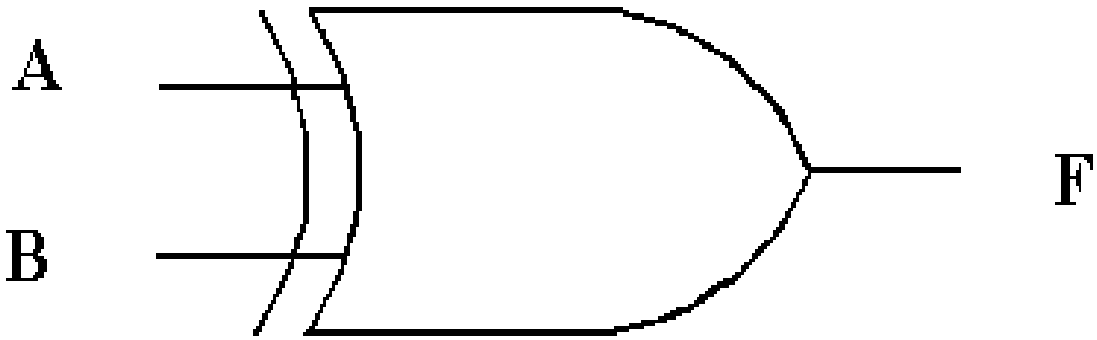
A	B	F
0	0	
0	1	
1	0	
1	1	

A	B	F
0	0	
0	1	
1	0	
1	1	

A	B	F
0	0	
0	1	
1	0	
1	1	

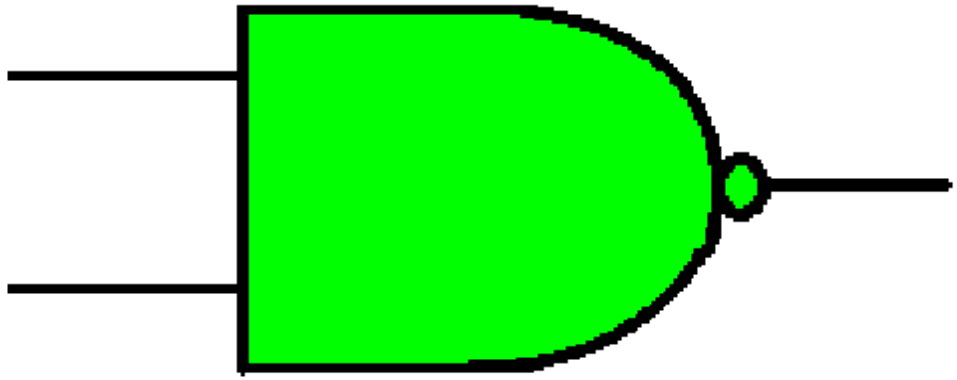


XOR OR gate logic symbol



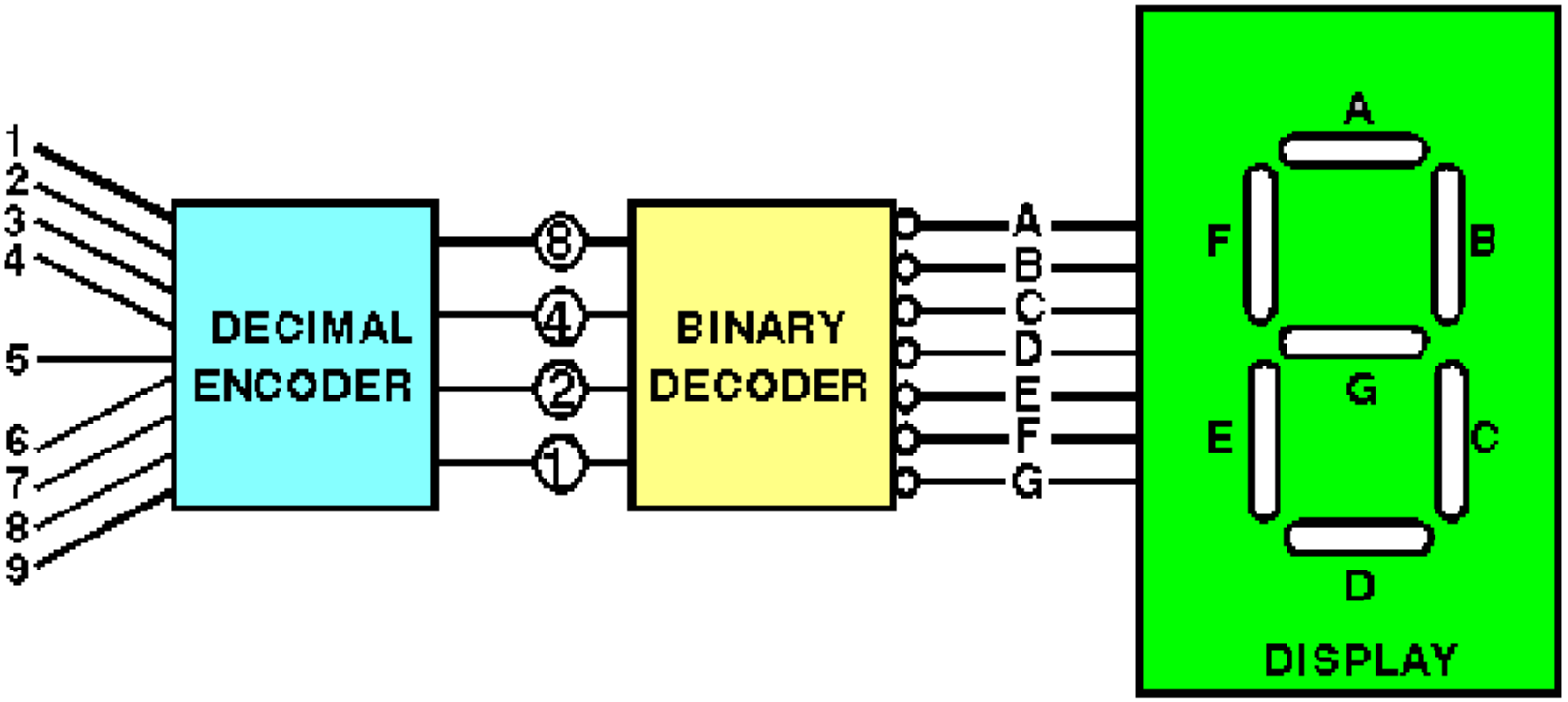
$A \oplus B = F$

Logic Expression for Exclusive OR gate

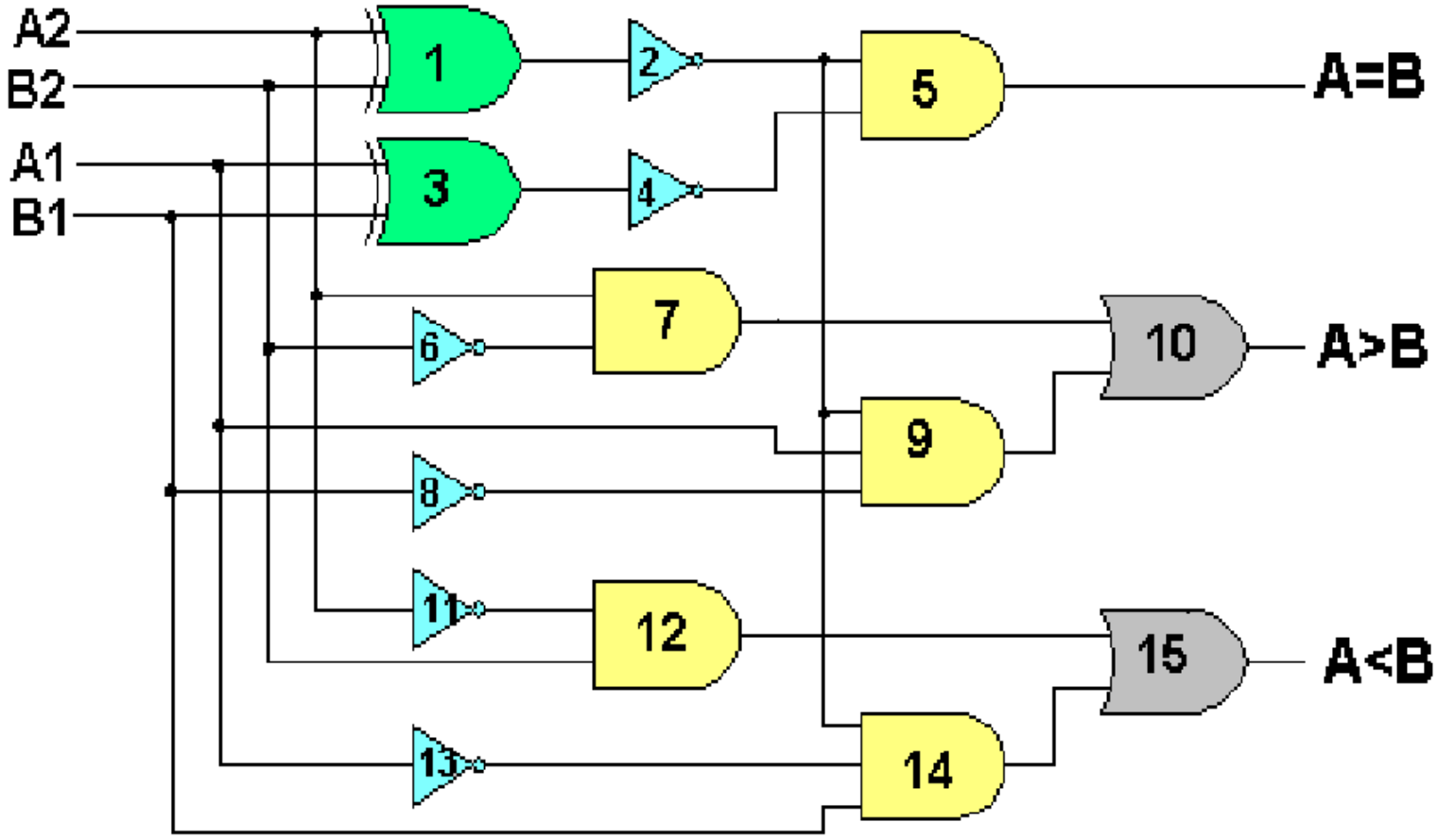


UNIVERSAL LOGIC GATE

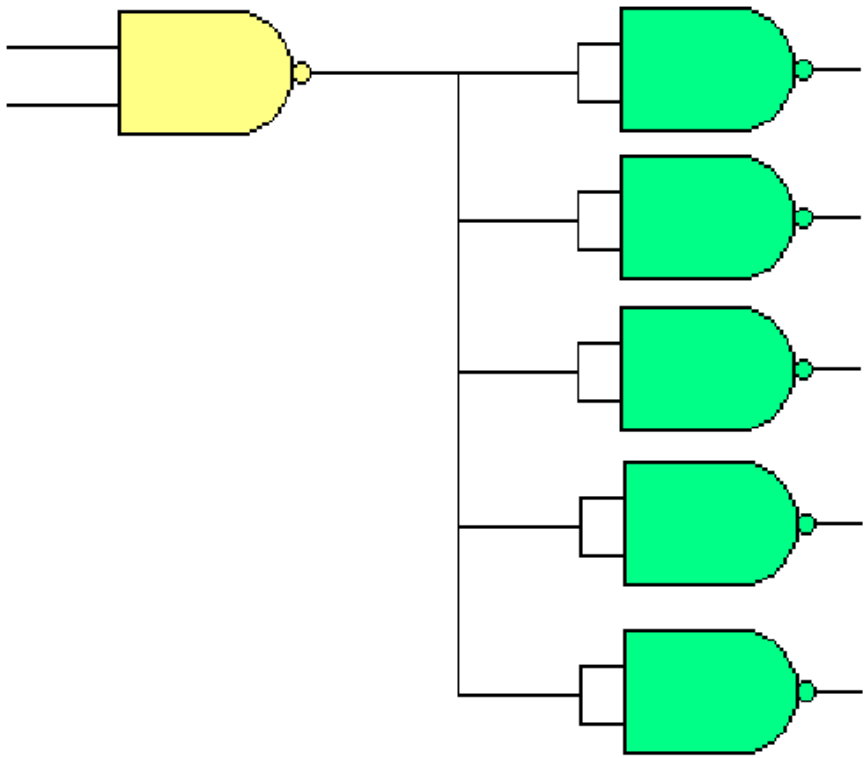
NAND GATE



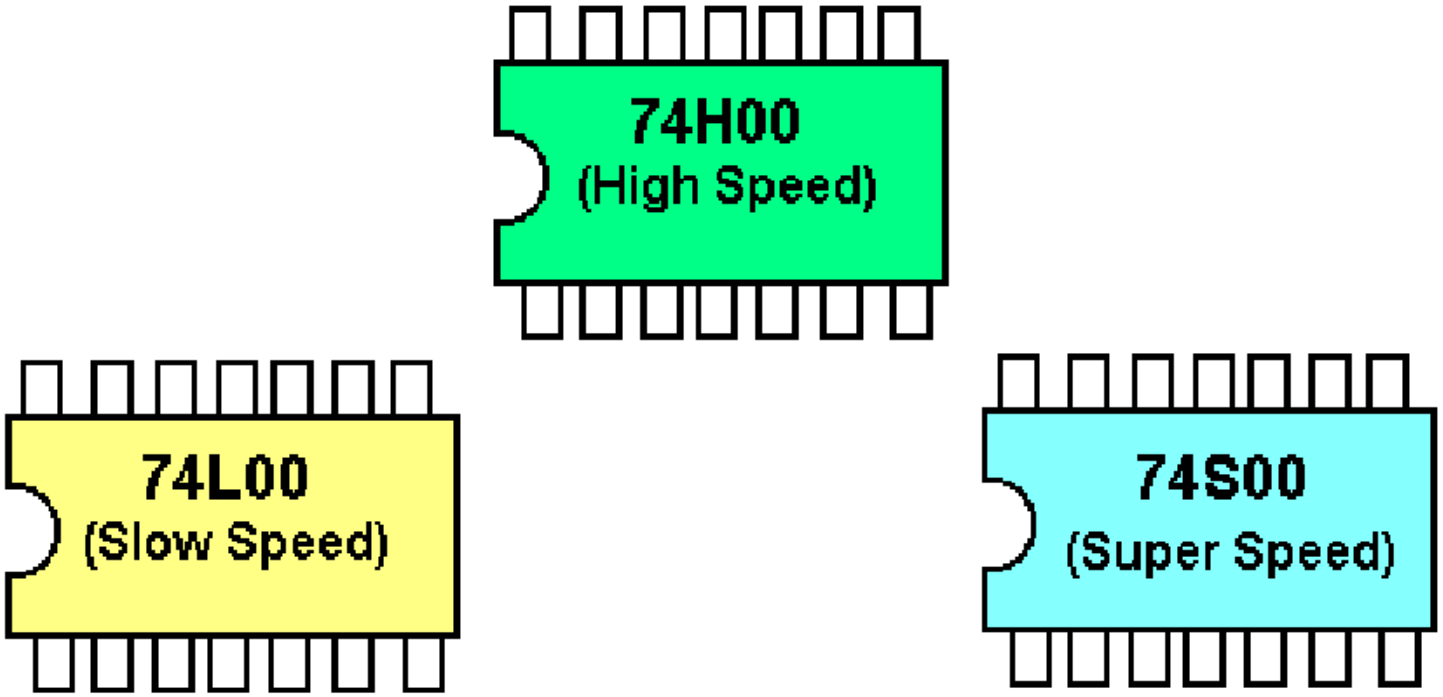
ENCODER AND DECODER CONVERSION CIRCUITS



Two Bit A-B Comparator

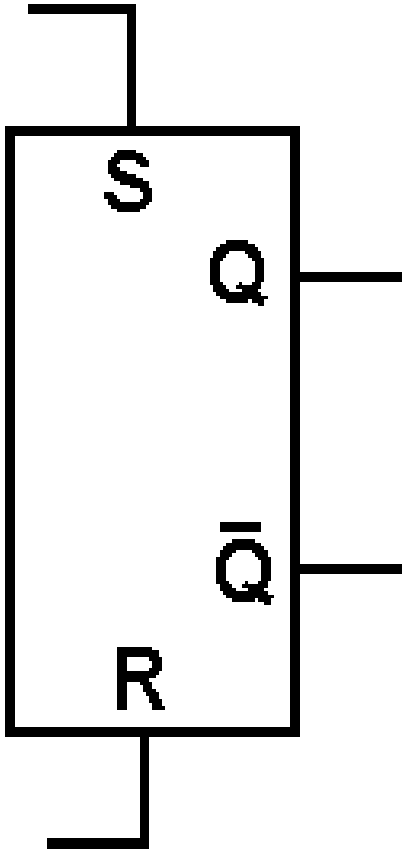


TTL IC Fan-Out (5)



TTL IC Switching Speed Codes

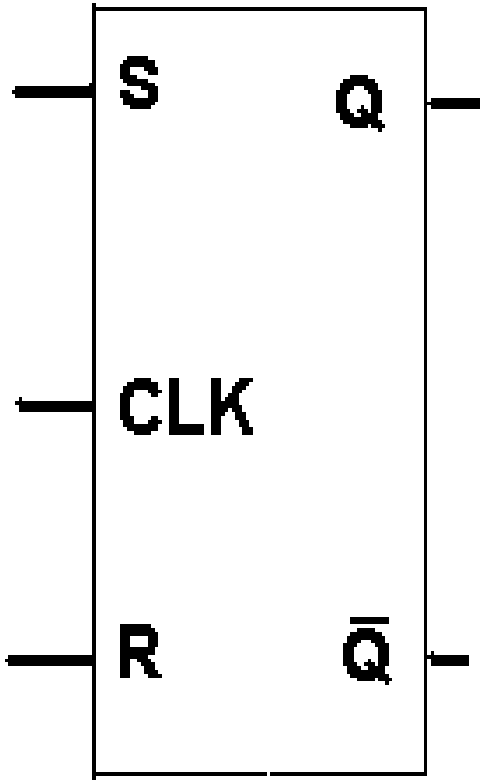
FLIP-FLOPS are temporary storage devices having two steady states. The circuit normally remains in one state until a pulse is applied to the input of the circuit, causing it to switch to the other state.

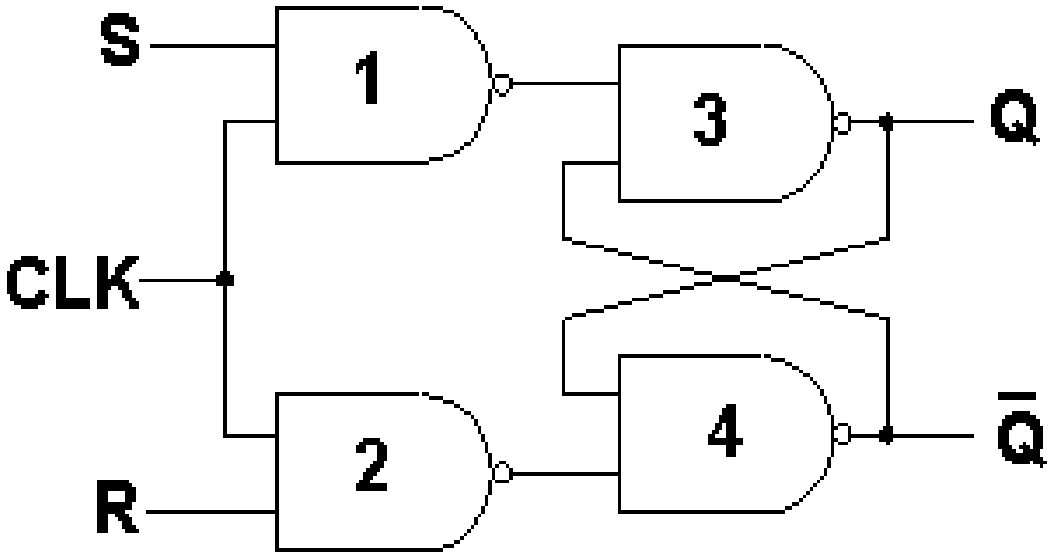


Graphic Symbol Active-High RS Flip-Flop

4-400-11

FLIP-FLOP TRIGGERING	
Level triggered	uses high or low pulse width
Edge triggered	uses leading or trailing edge
Pulse triggered	uses high and low (level) or leading and trailing (edge)

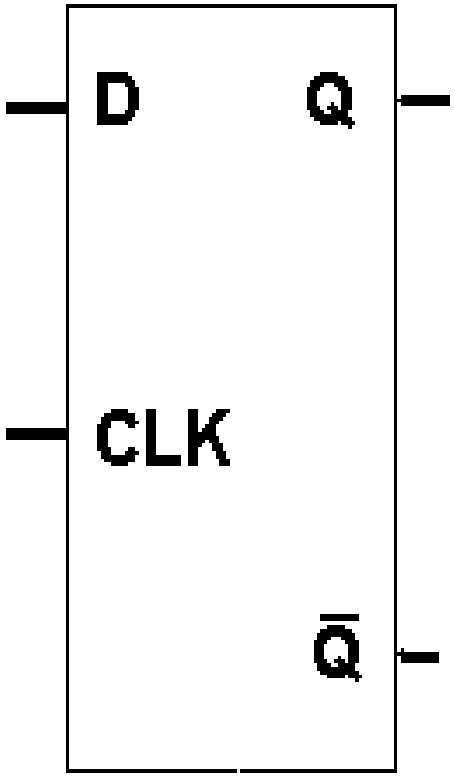


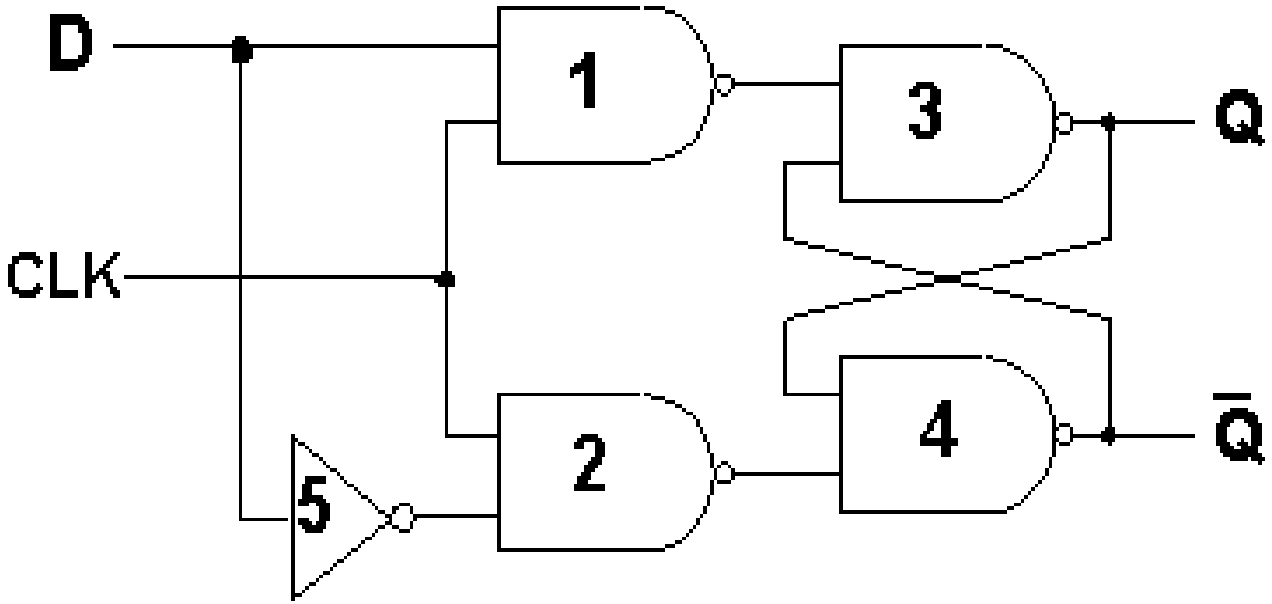


Active-High Clocked RS Flip-Flop

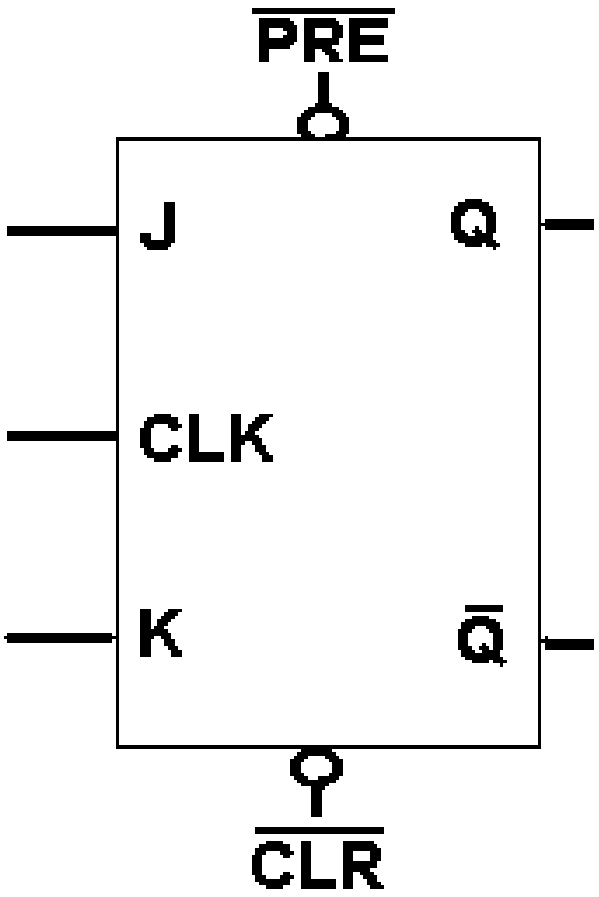
Inputs			*Outputs*		
S	R	CLK	Q	$\bar{Q}$	*Comments*
0	0	X	NC	NC	*No change*
0	1	1	0	1	*Latch Resets*
1	0	1	1	0	*Latch Sets*
1	1	1	?	?	*Invalid condition*

Active-High Clocked RS Truth Table



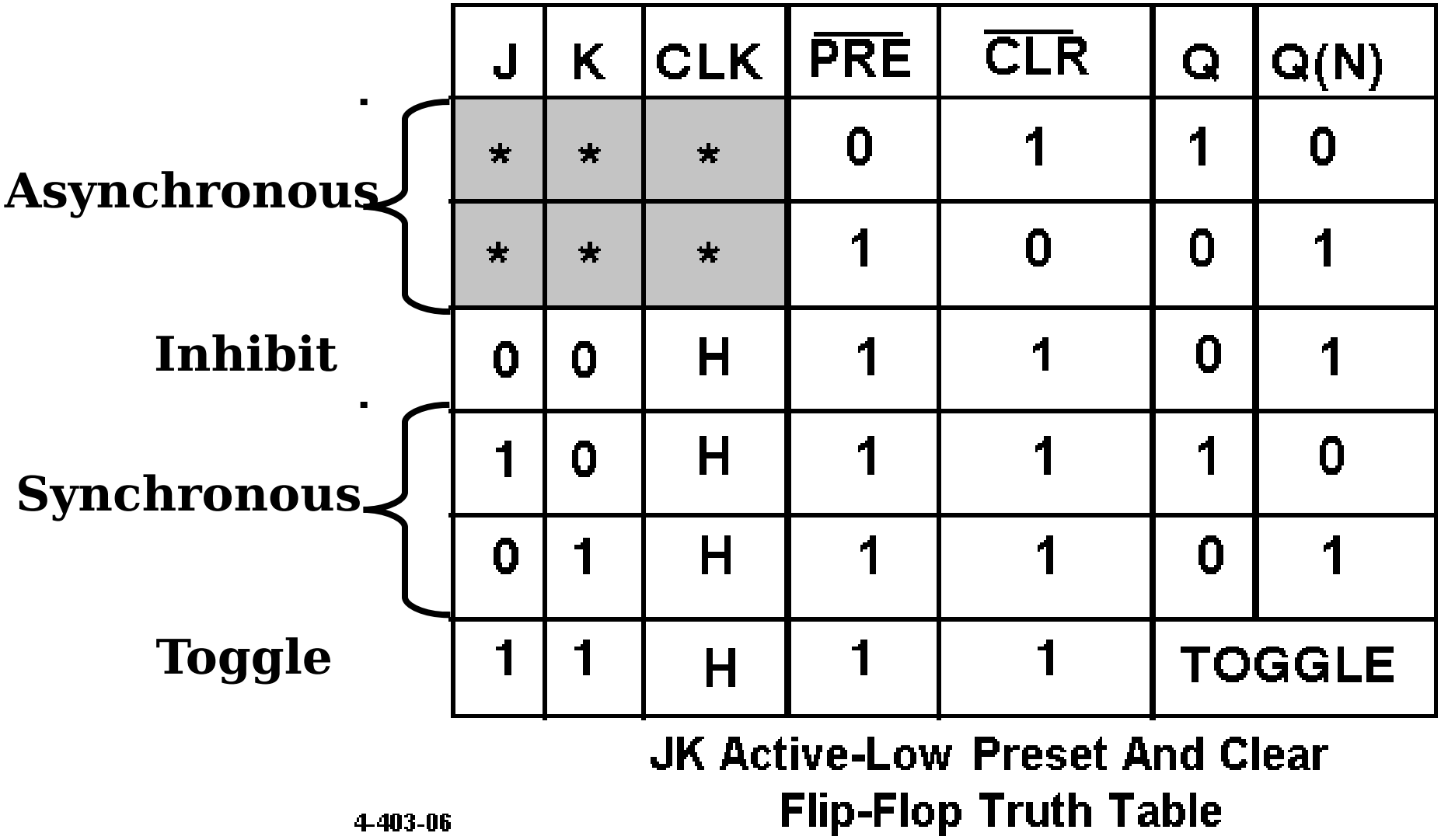


High Gated D Type Flip-Flop



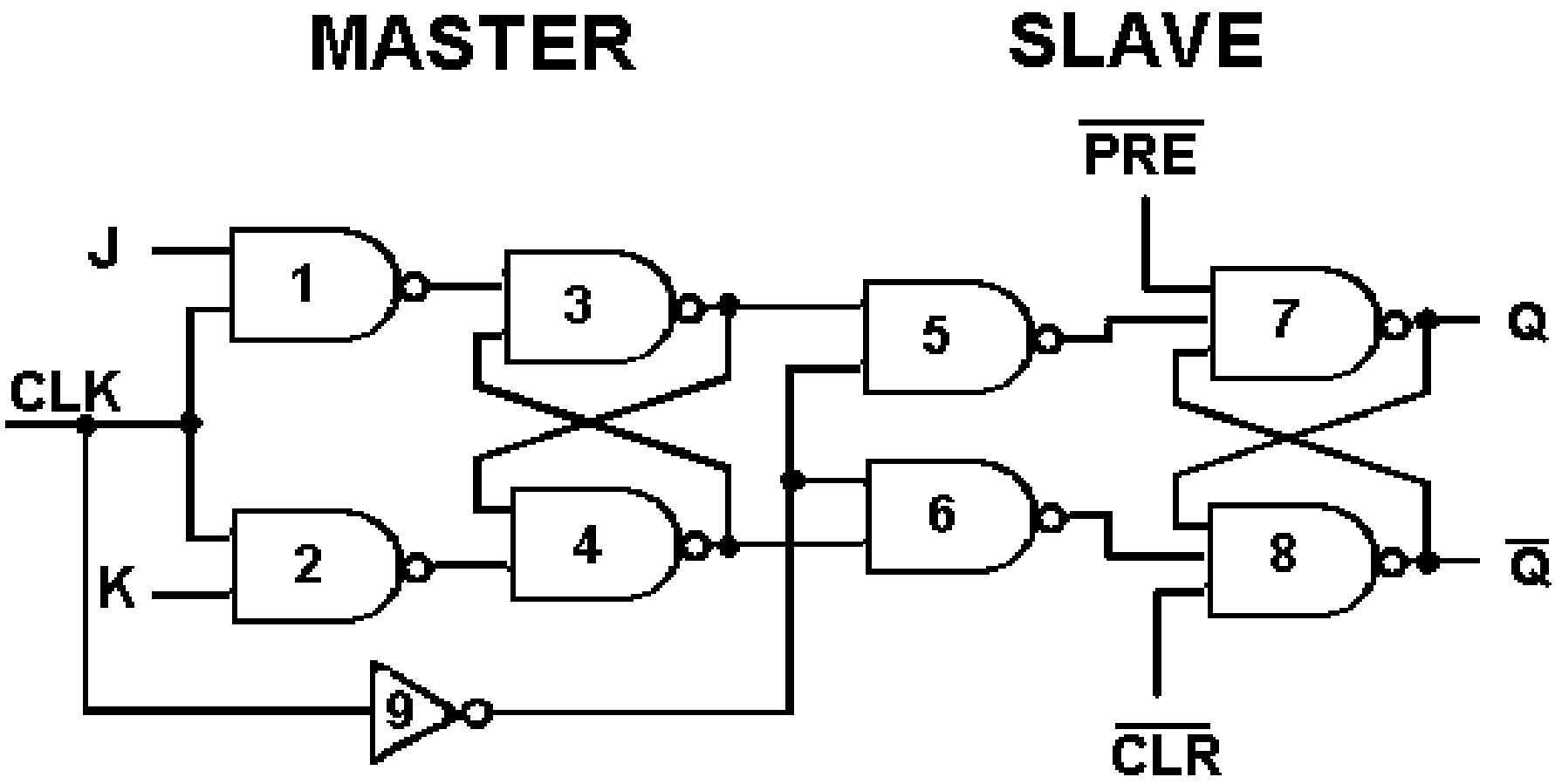
Graphic Symbol JK Flip-Flop

A 403 04

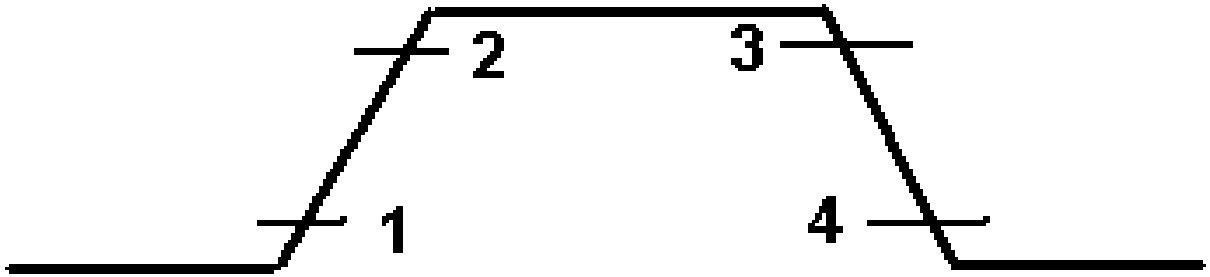


JK Active-Low Preset And Clear
Flip-Flop Truth Table

4-403-06



Master Slave J-K Flip-Flop



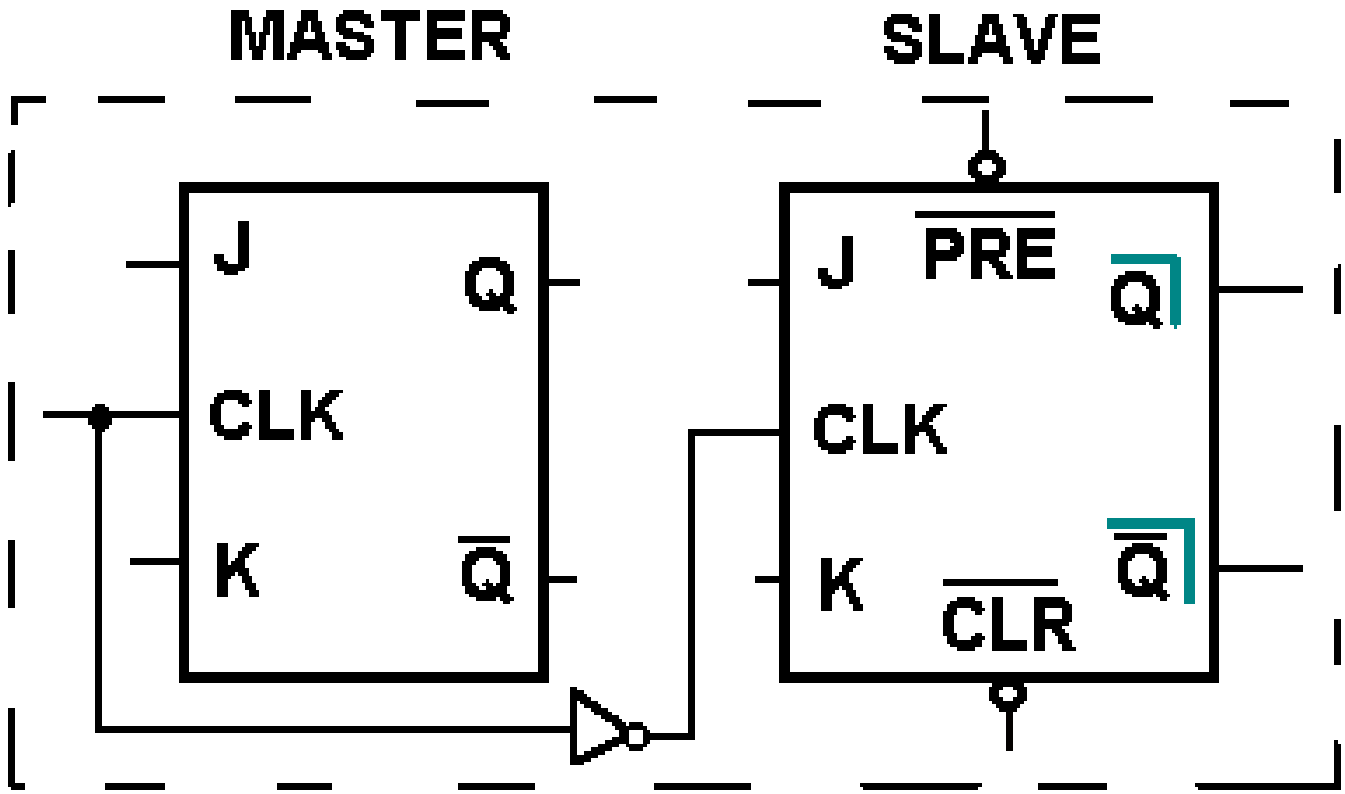
Point 1: Clock pulse starts positive, master and slave are isolated.

Point 2: J and K inputs transfered into master.

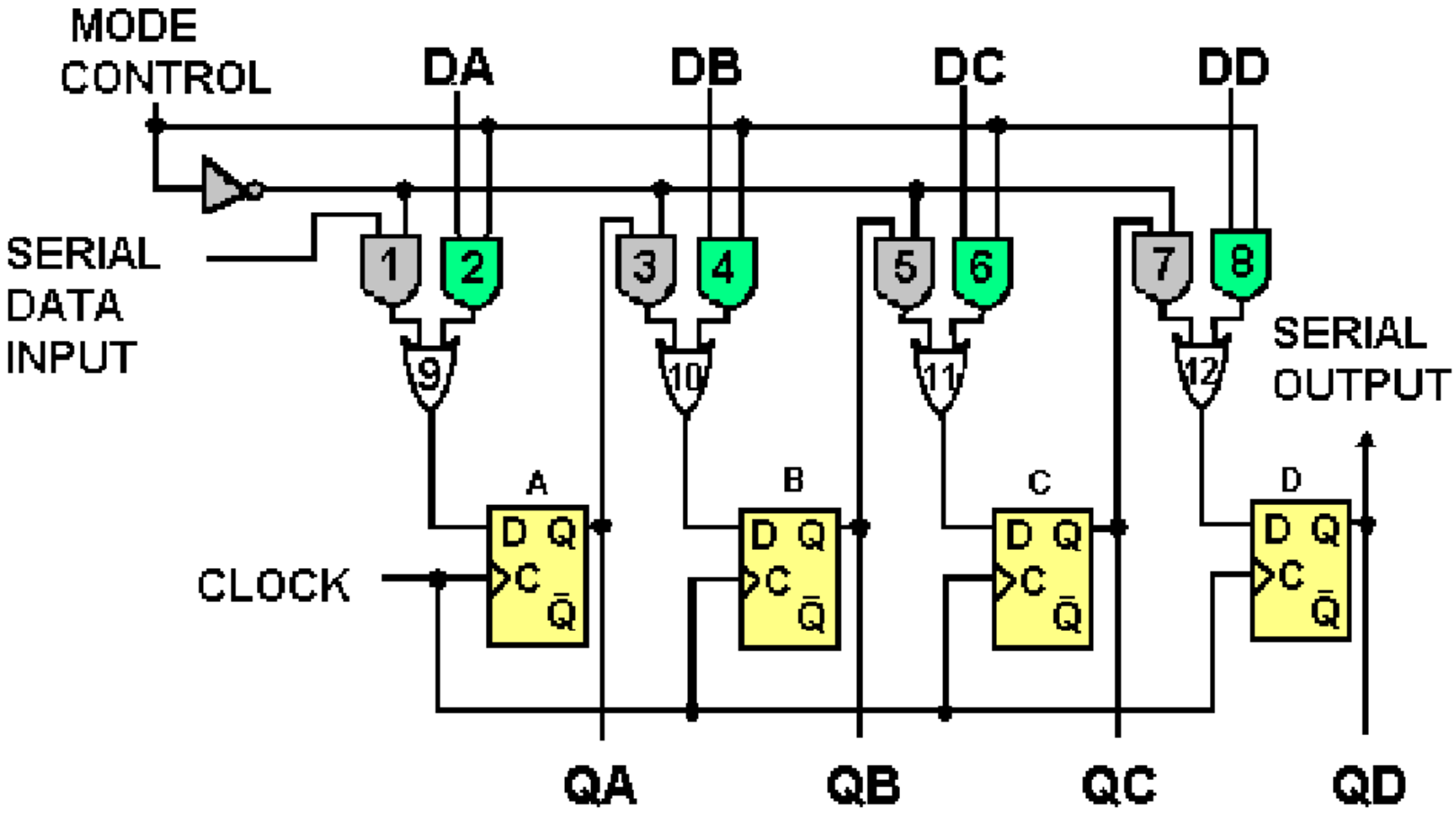
Point 3: J and K inputs stored into master.

Point 4: J and K outputs transferred to slave.

J-K Master Slave Gated Clock Pulse

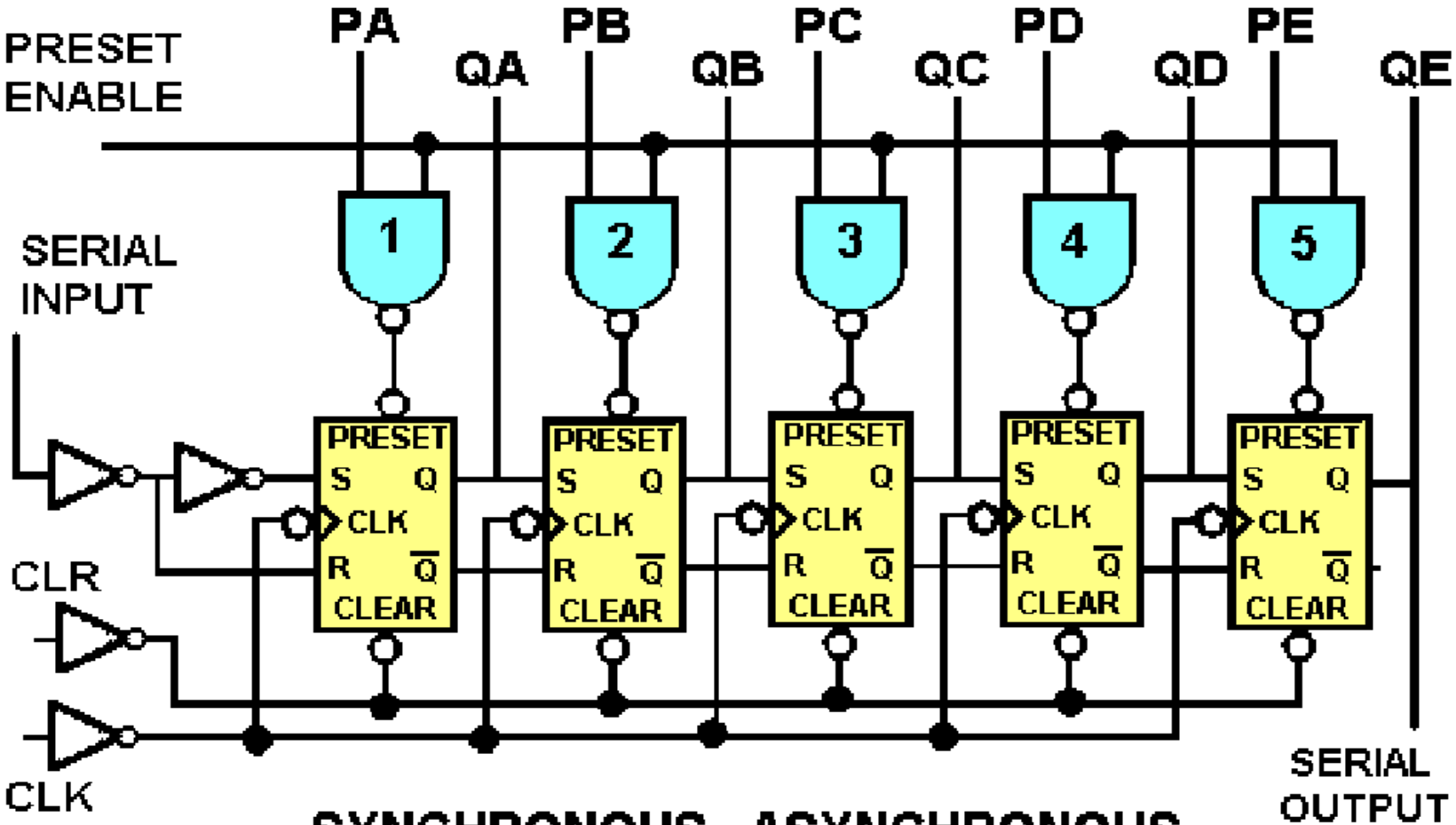


Graphic Symbol Master Slave Flip-flop



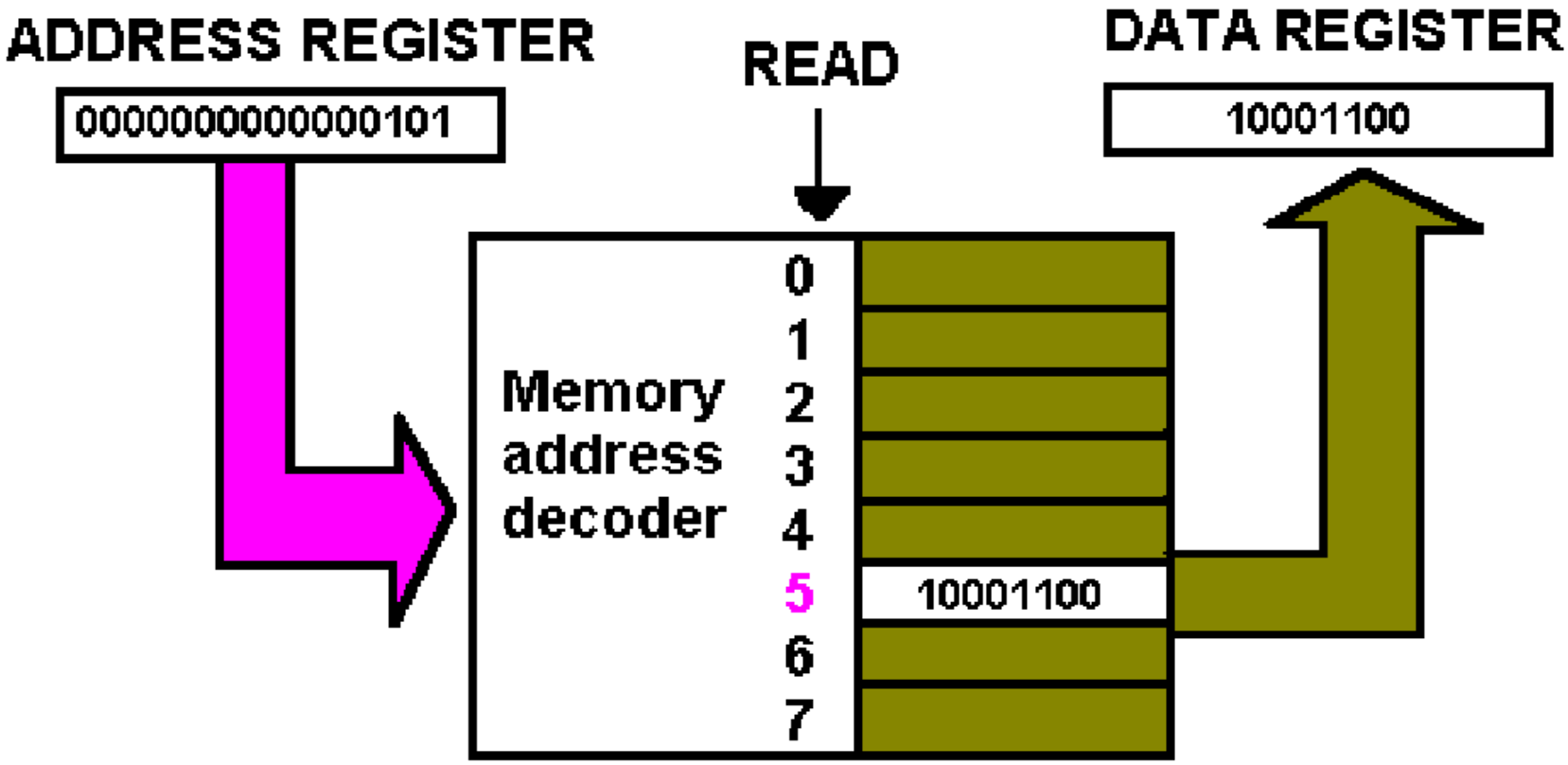
4 BIT SHIFT REGISTER MODE CONTROL

EL13-S12

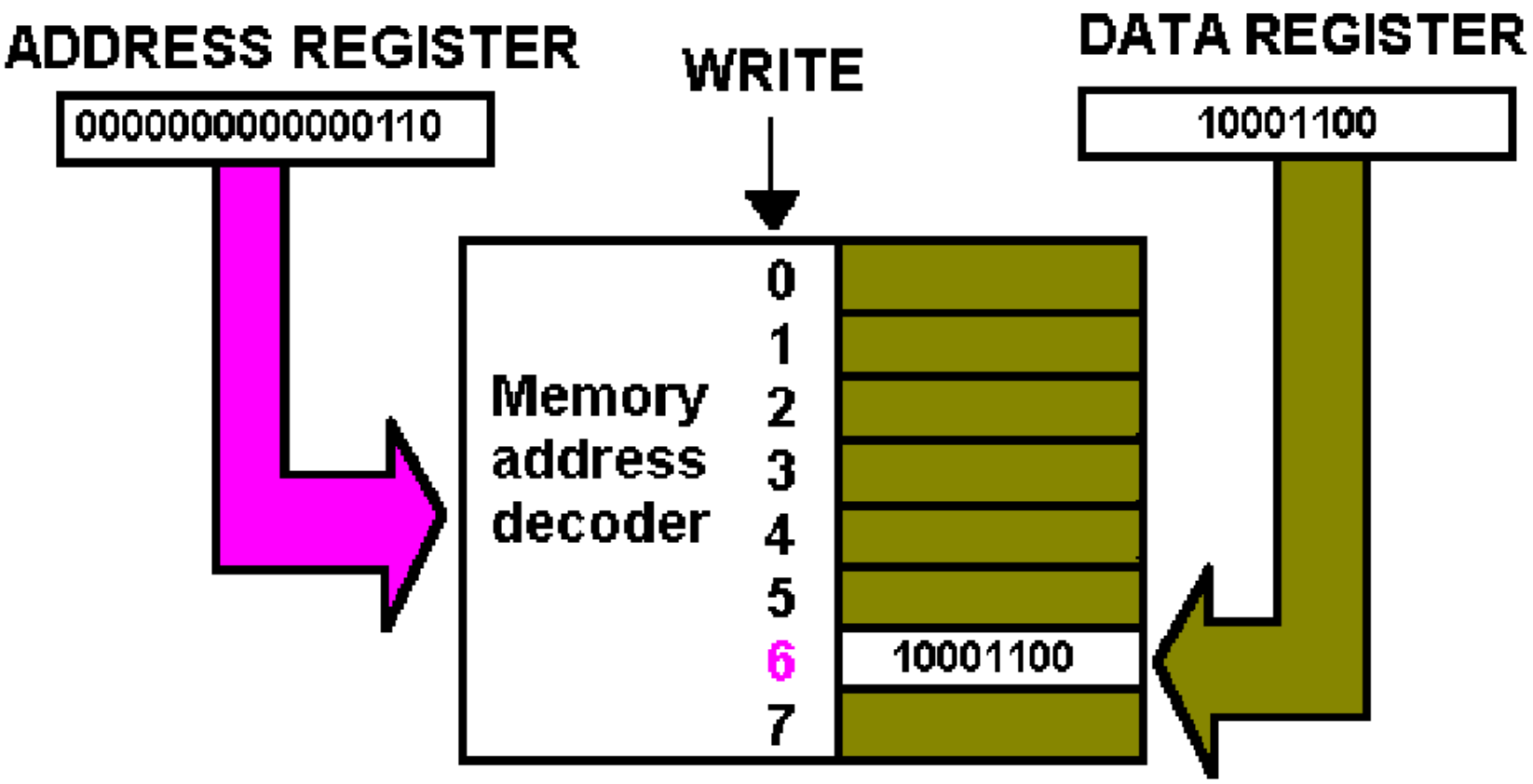


SYNCHRONOUS - ASYNCHRONOUS
5 BIT SHIFT REGISTER

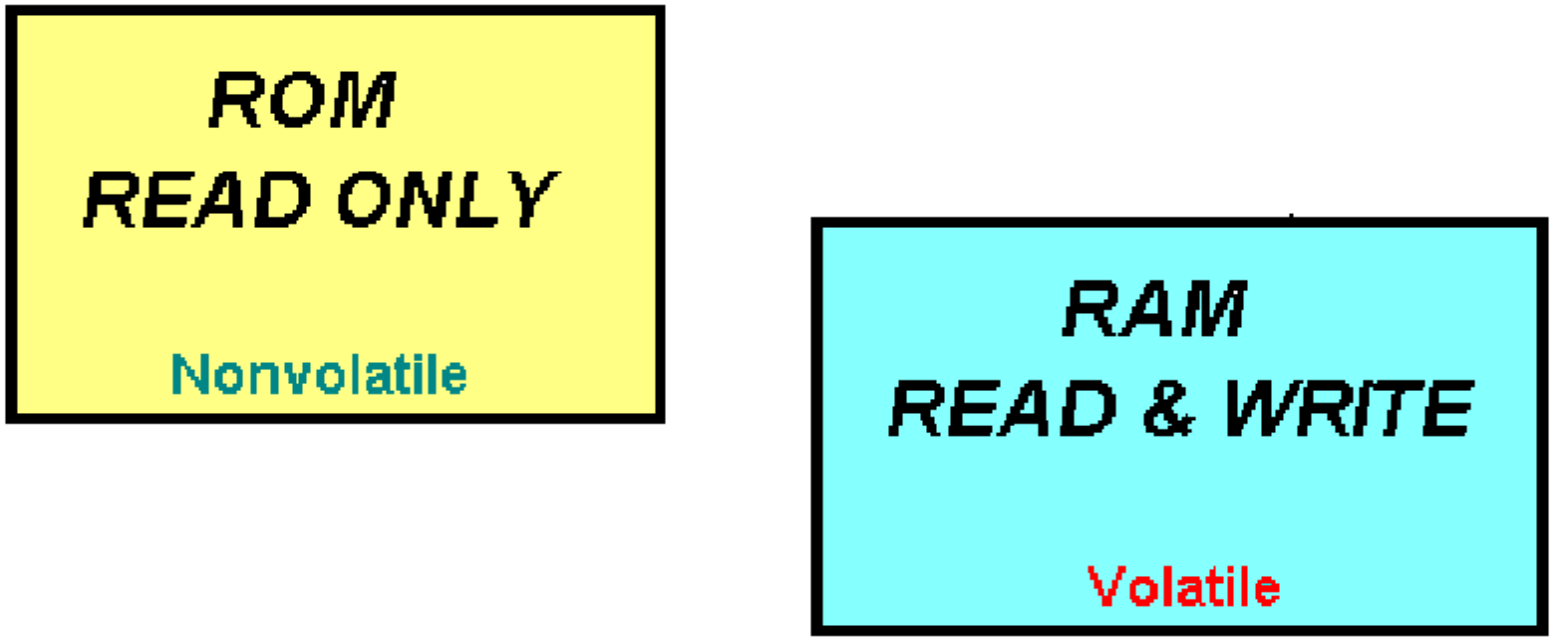
EL13-S16



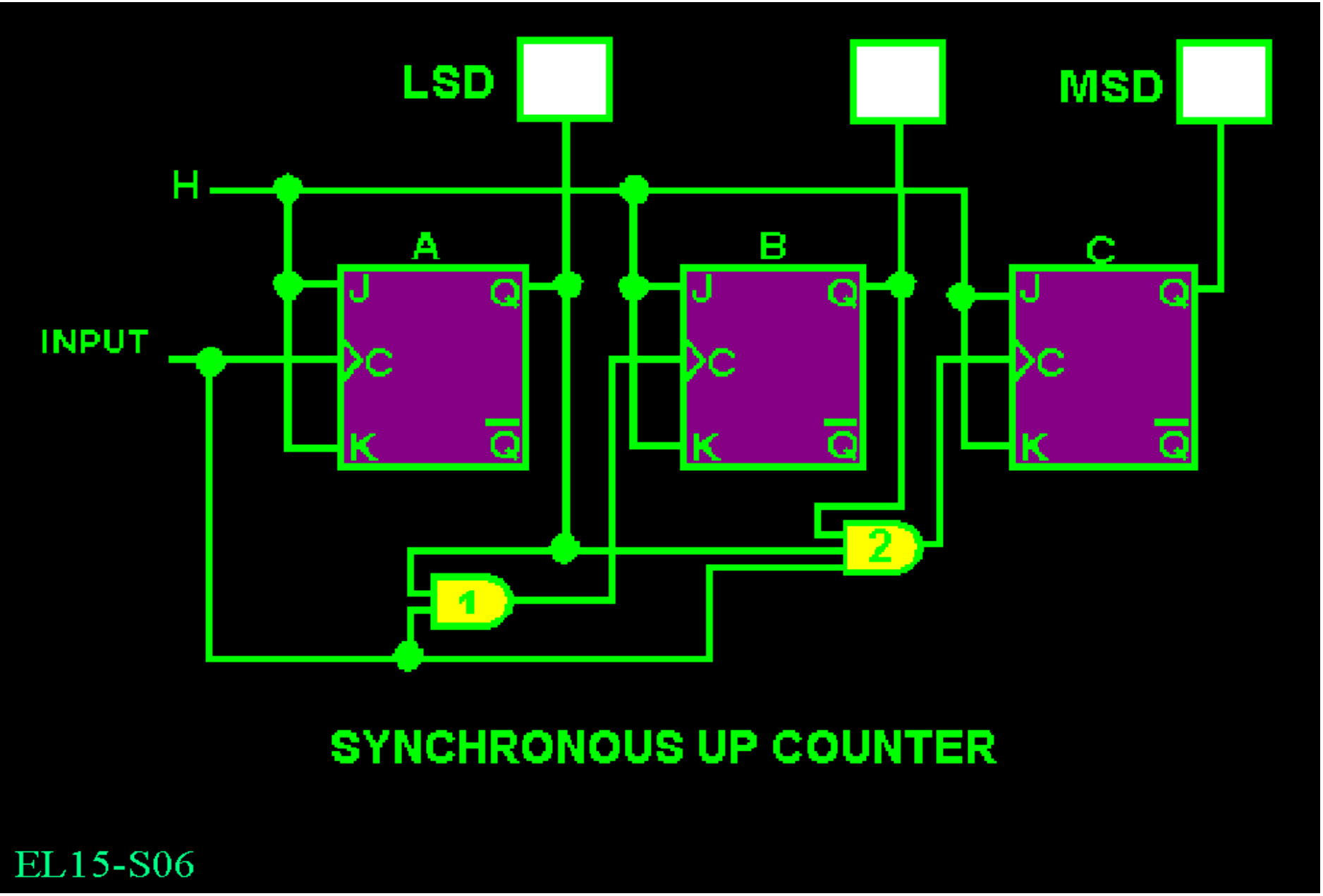
MEMORY READ OPERATION

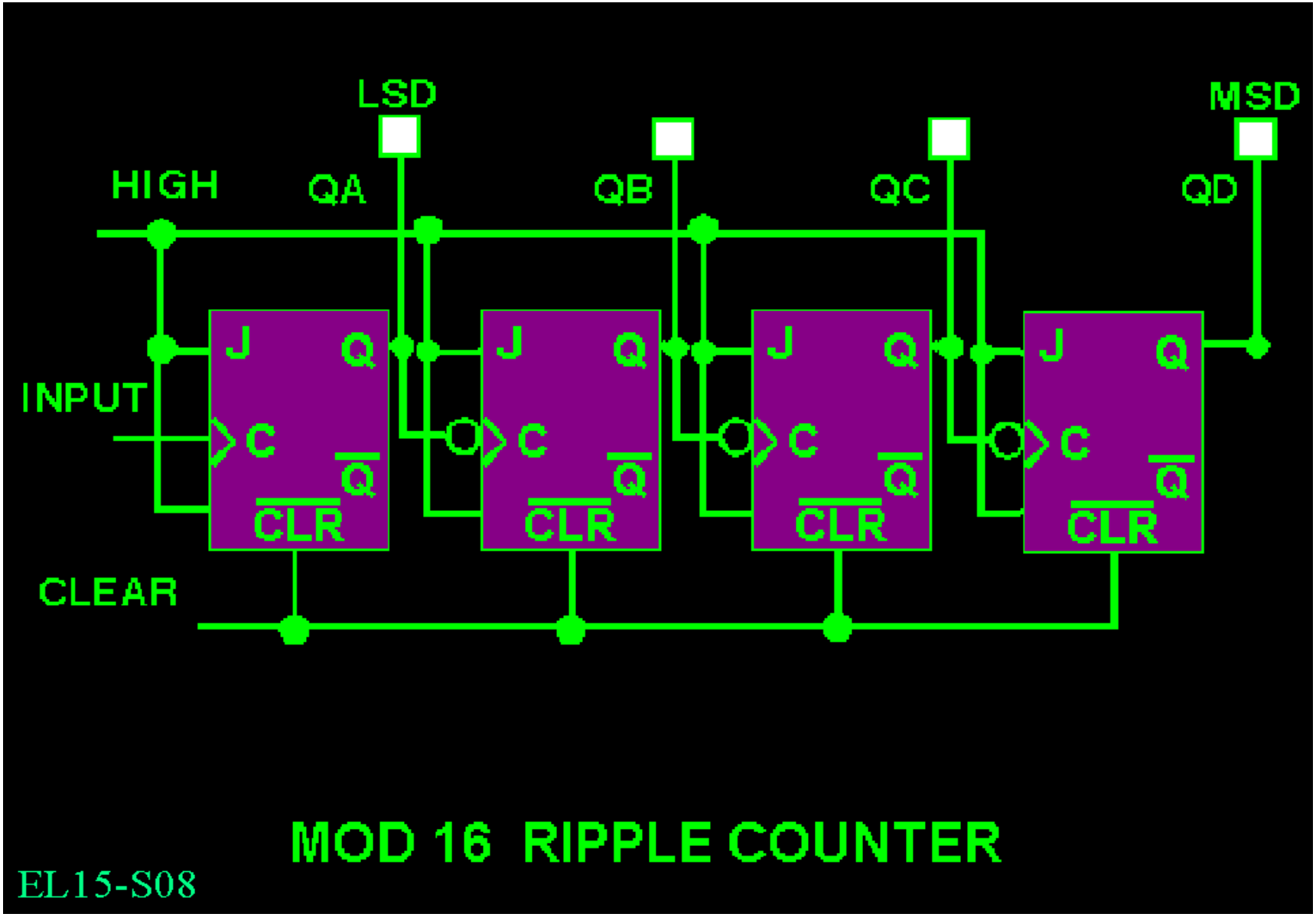


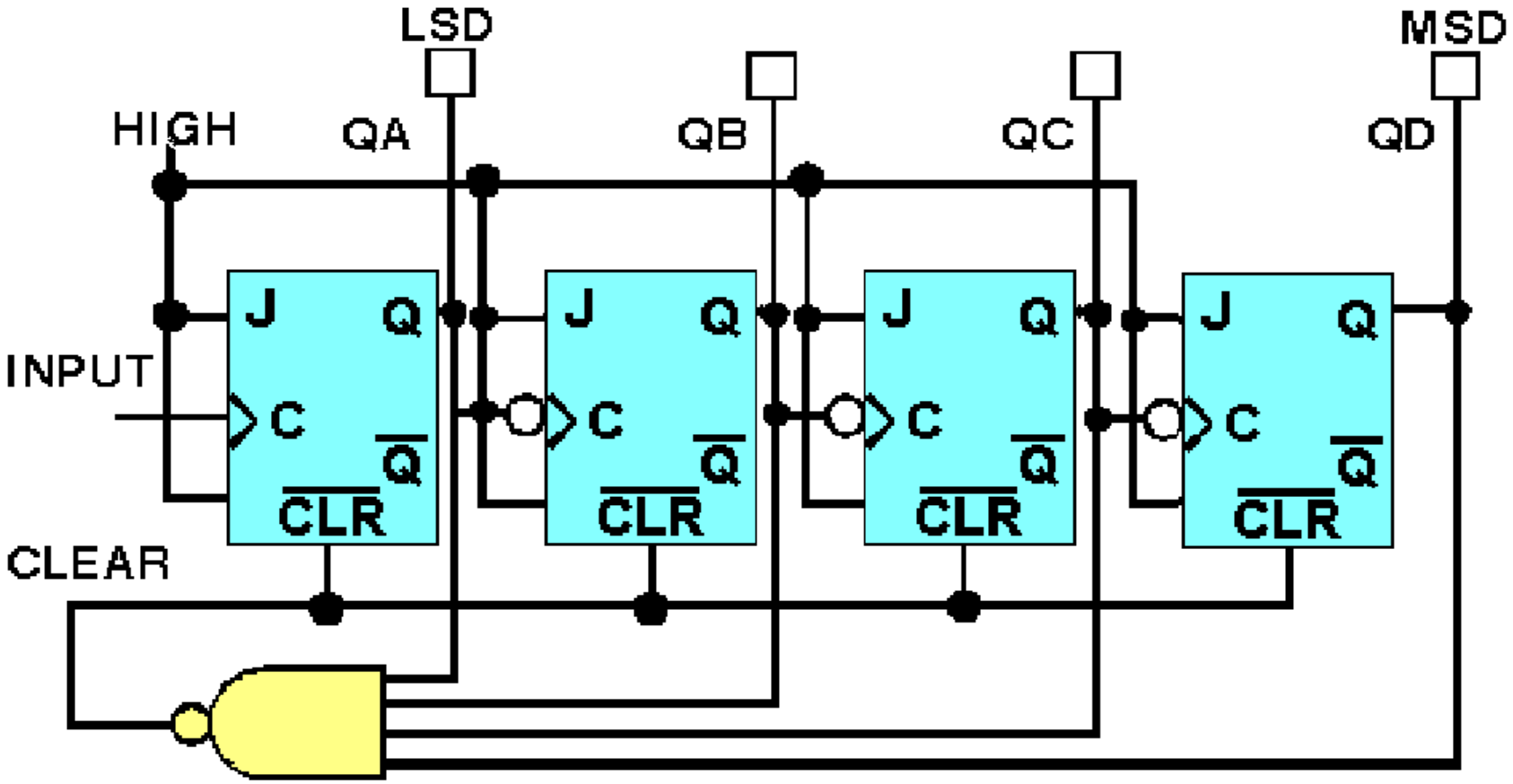
MEMORY WRITE OPERATION



Semiconductor Memories

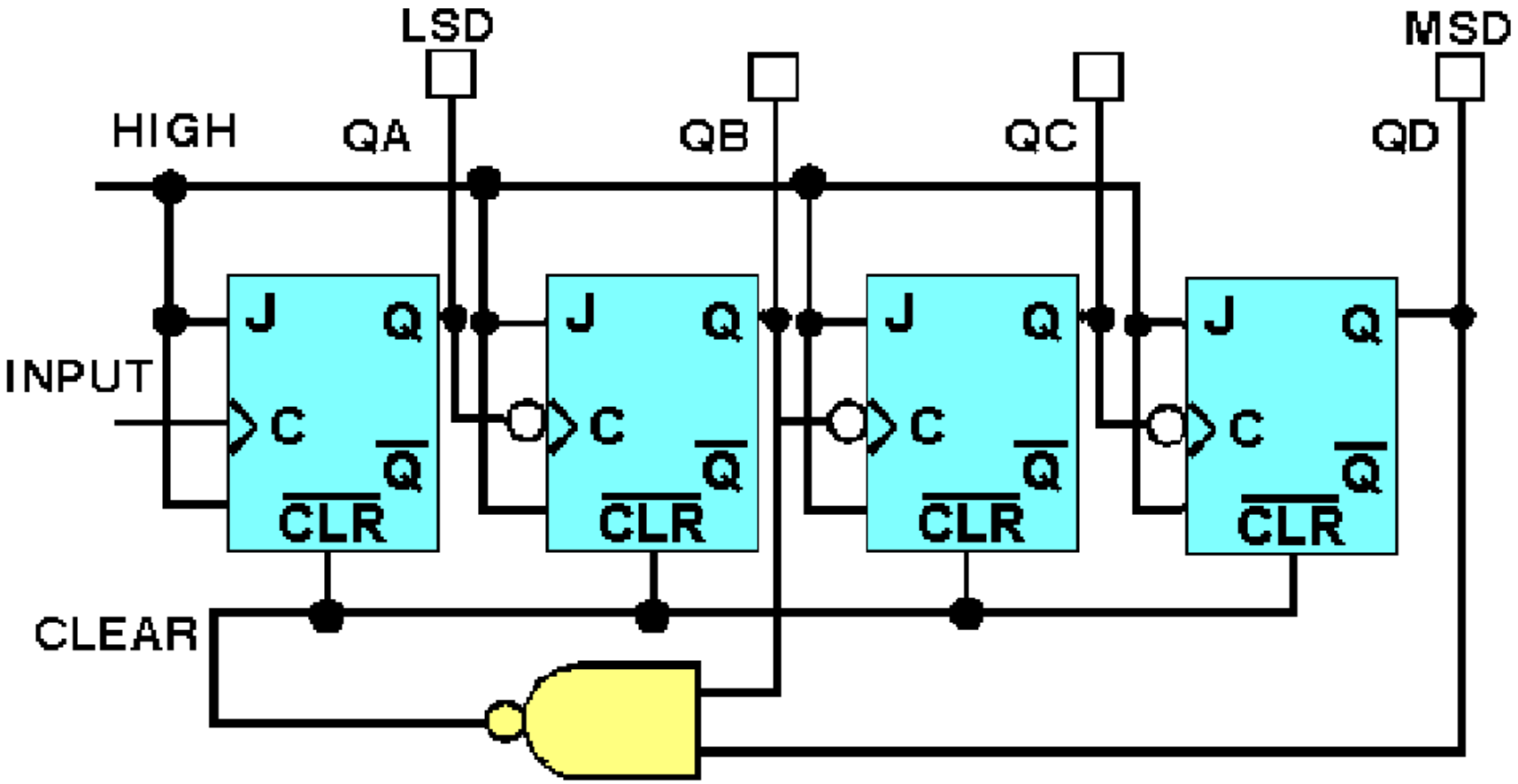

LSD
MSD
H
A
B
C
J
Q
C
K
Q
INPUT
1
2
SYNCHRONOUS UP COUNTER


LSD
MSD
HIGH
QA
QB
QC
QD
J
Q
C
Q
CLR
INPUT
CLEAR
MOD 16 RIPPLE COUNTER
EL15-S08



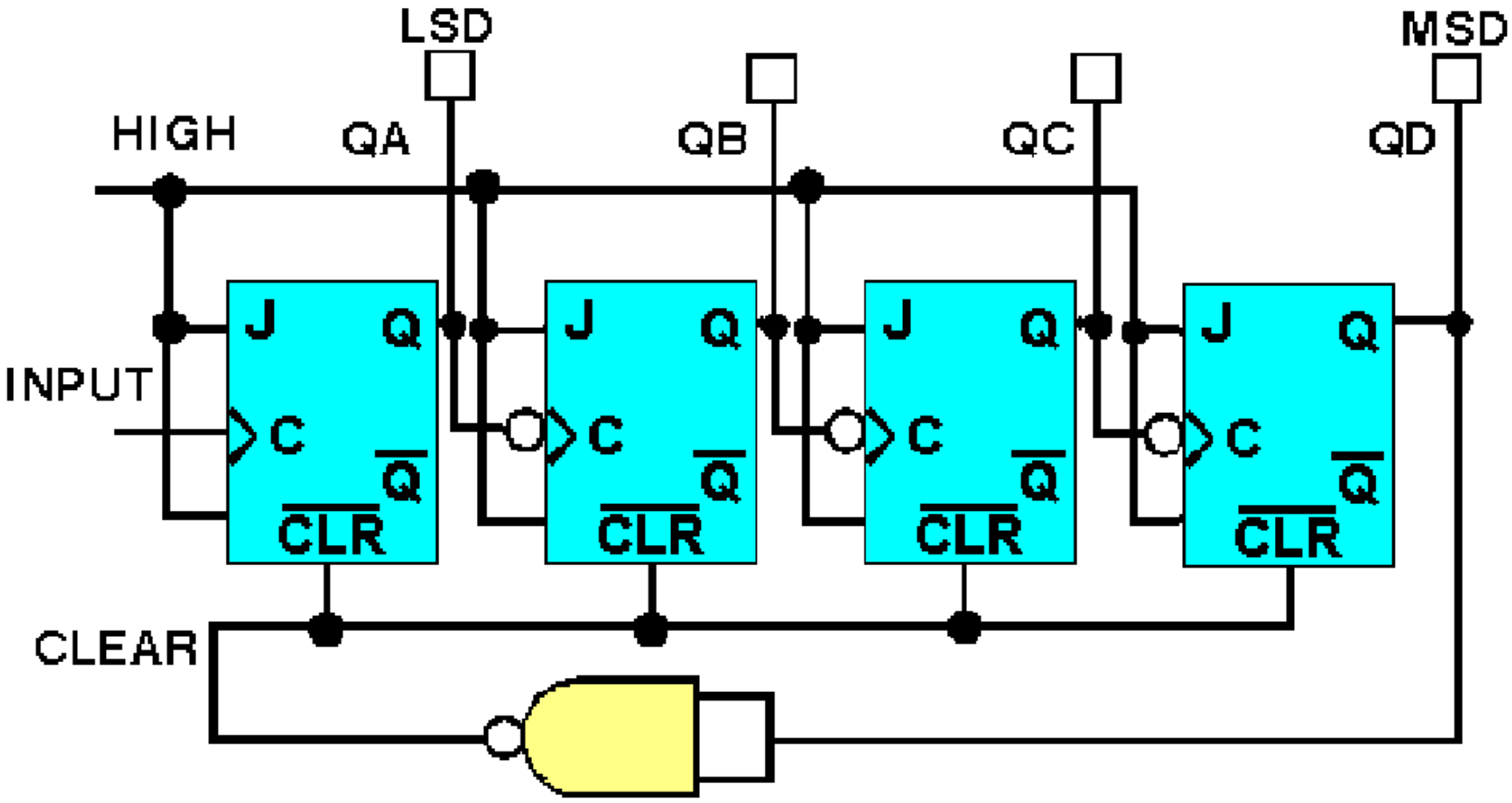
MOD 15 RIPPLE UP COUNTER

EL15-S09



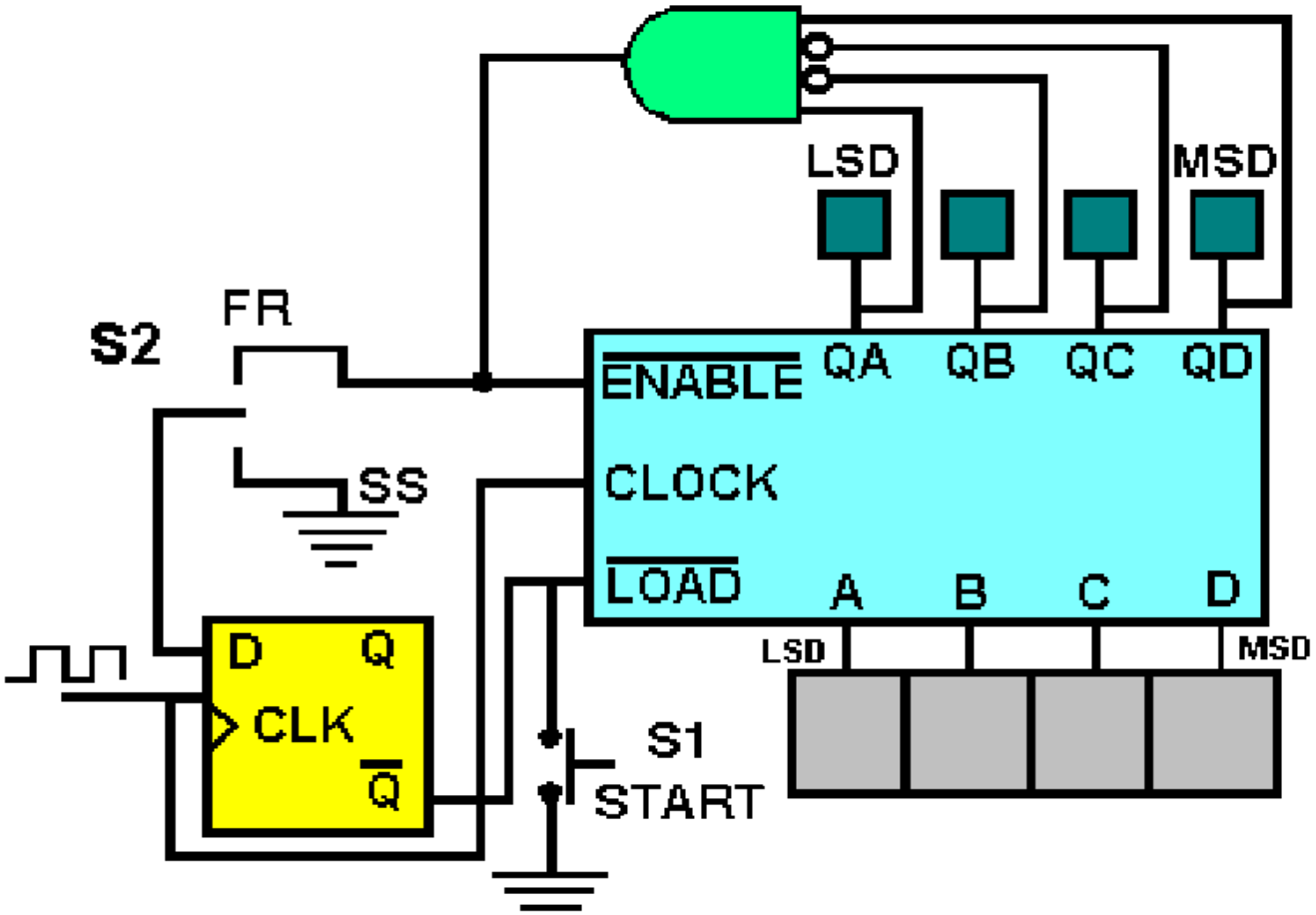
MOD 10 RIPPLE UP COUNTER

EL15-S10



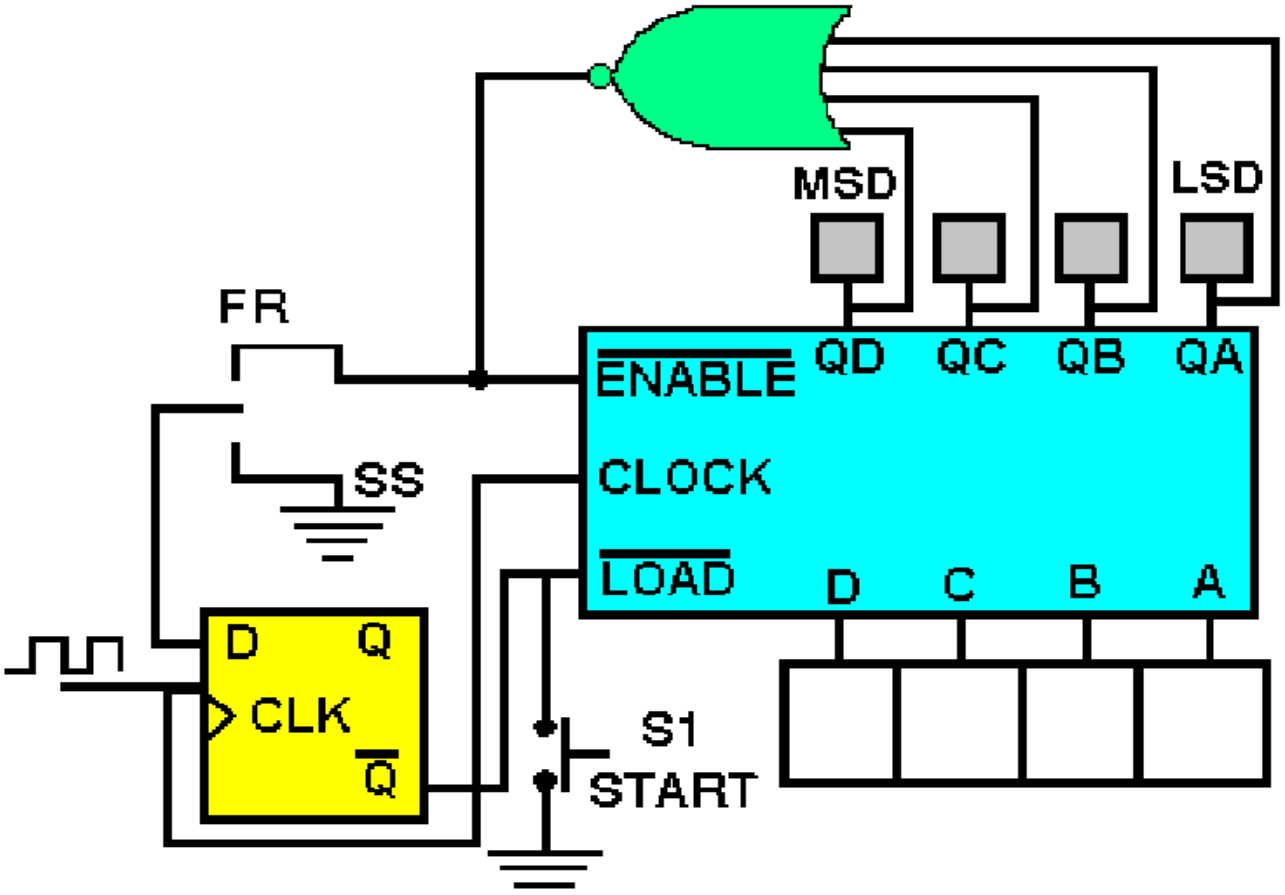
MOD 8 RIPPLE UP COUNTER

EL15-S11

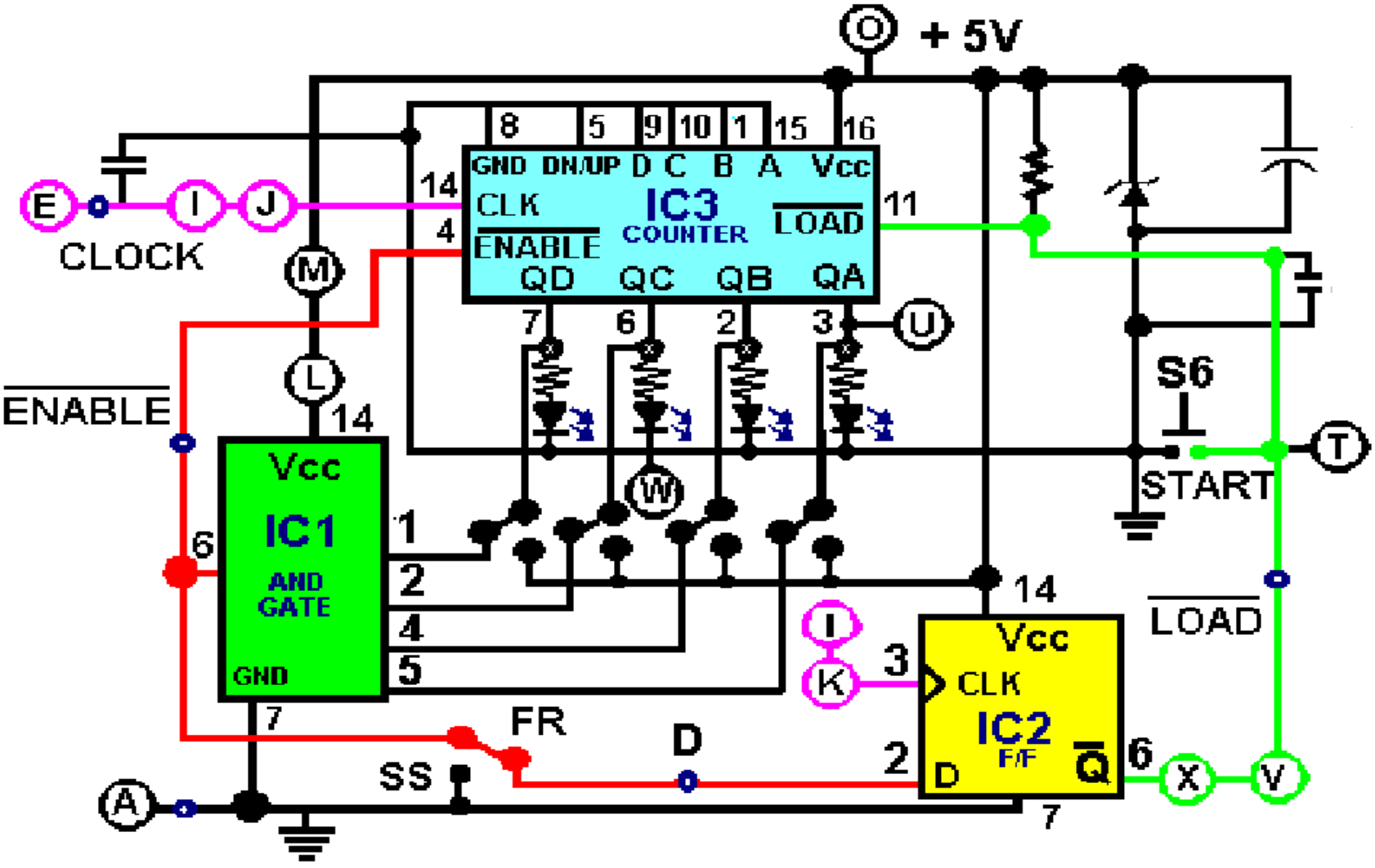


VARIABLE MODULUS UP COUNTER

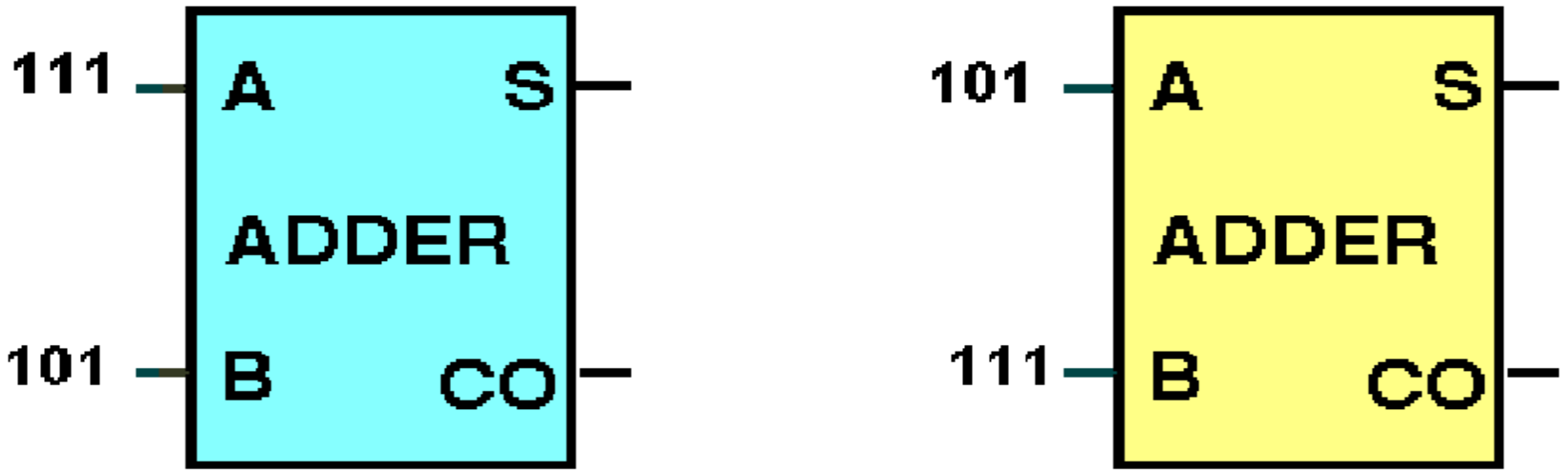
EL15-S14



DOWN COUNTER MODES OF OPERATION

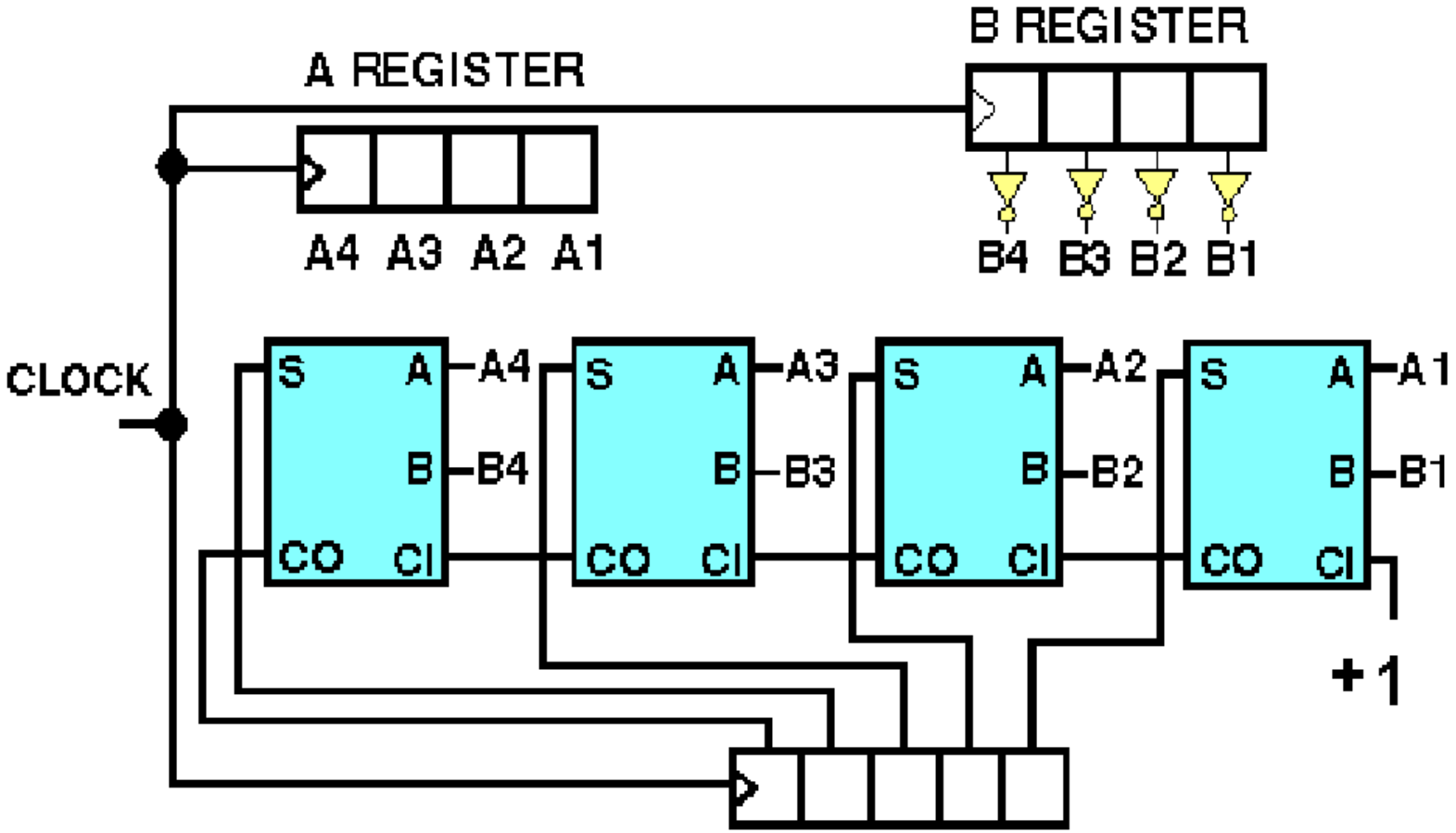

O
+ 5V
8
5
9
10
1
15
16
GND DN/UP D C B A Vcc
CLK
IC3
COUNTER
LOAD
ENABLE
QD QC QB QA
14
4
11
7
6
2
3
U
E
I
J
CLOCK
M
L
14
ENABLE
S6
START
T
W
Vcc
IC1
AND
GATE
GND
6
1
2
4
5
7
14
I
K
3
Vcc
CLK
IC2
F/F
D
Q̄
2
6
7
LOAD
X
V
FR
D
SS
A

EL15-S16

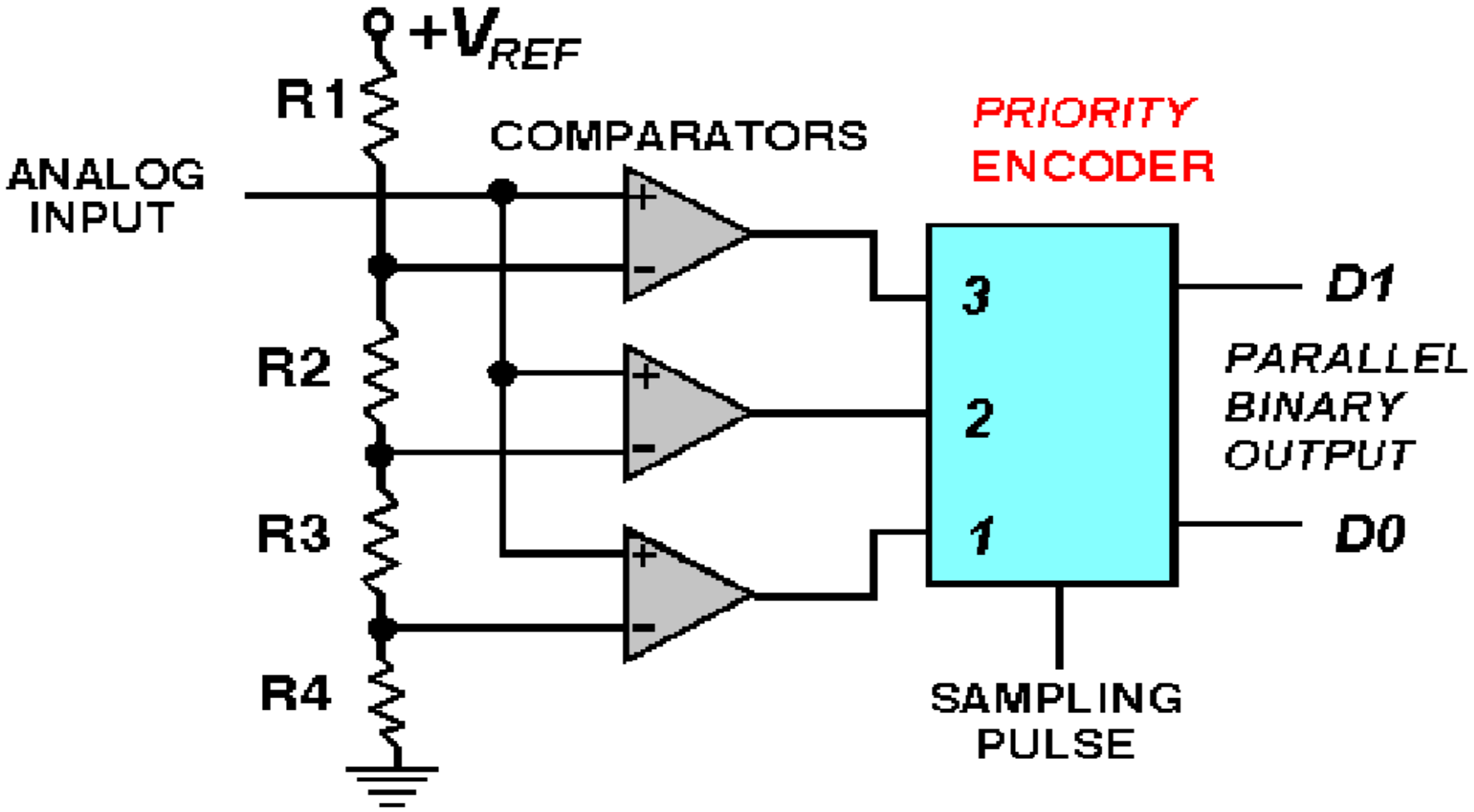


SUBTRACTOR TWO'S COMPLEMENT

EL15-S29

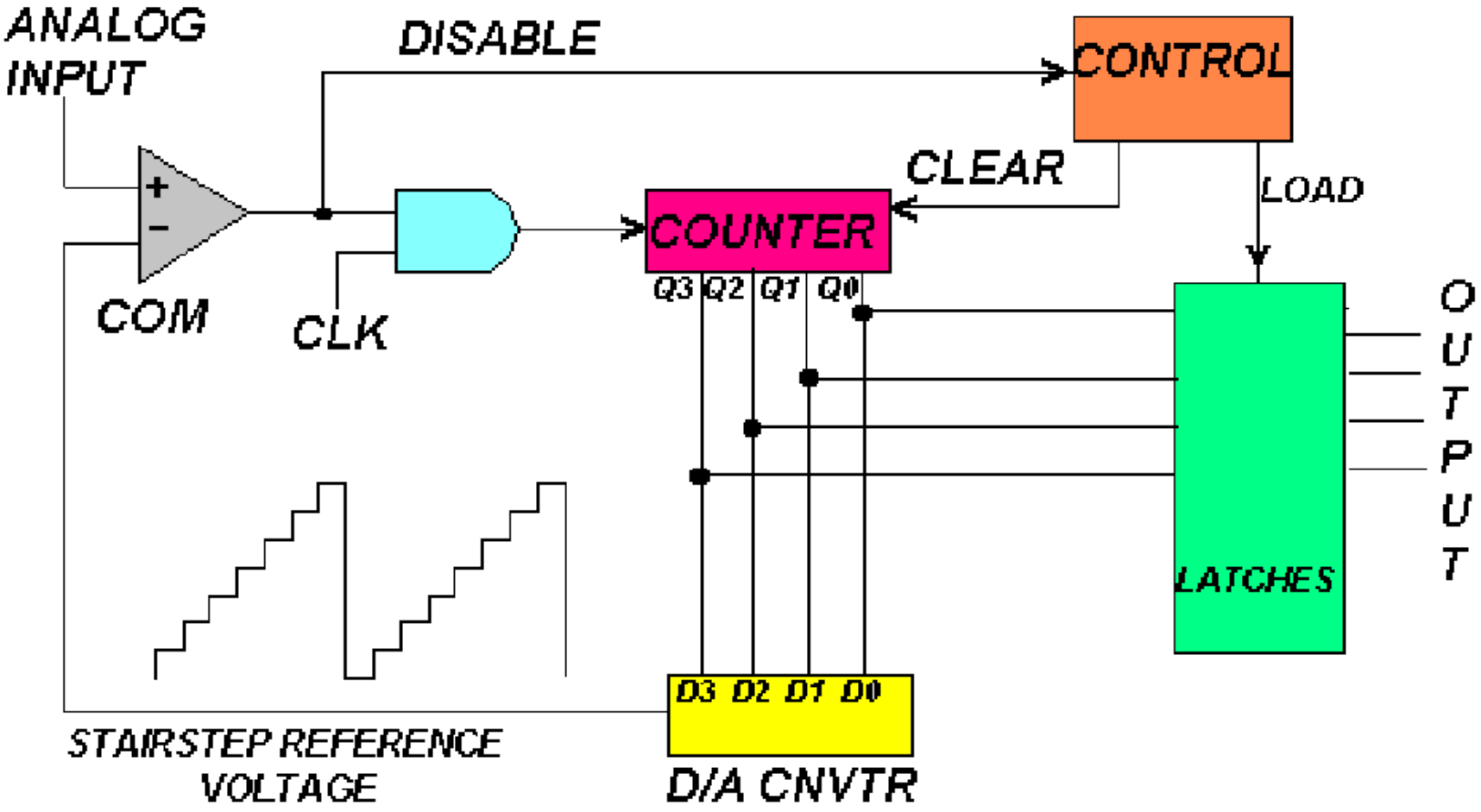


4 BIT PARALLEL SUBTRACTOR



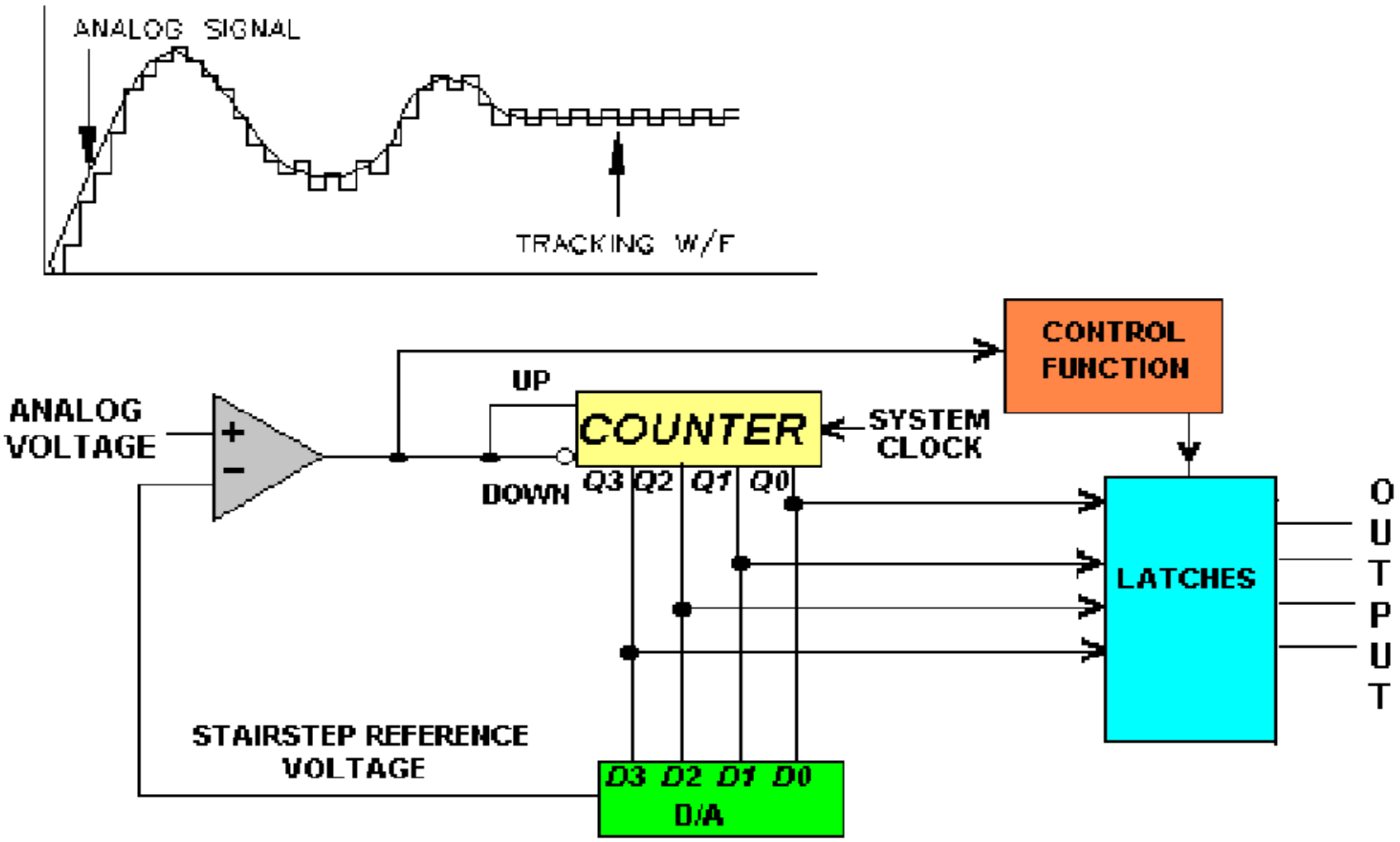
SIMULTANEOUS A/D CONVERTER

EL17-S05



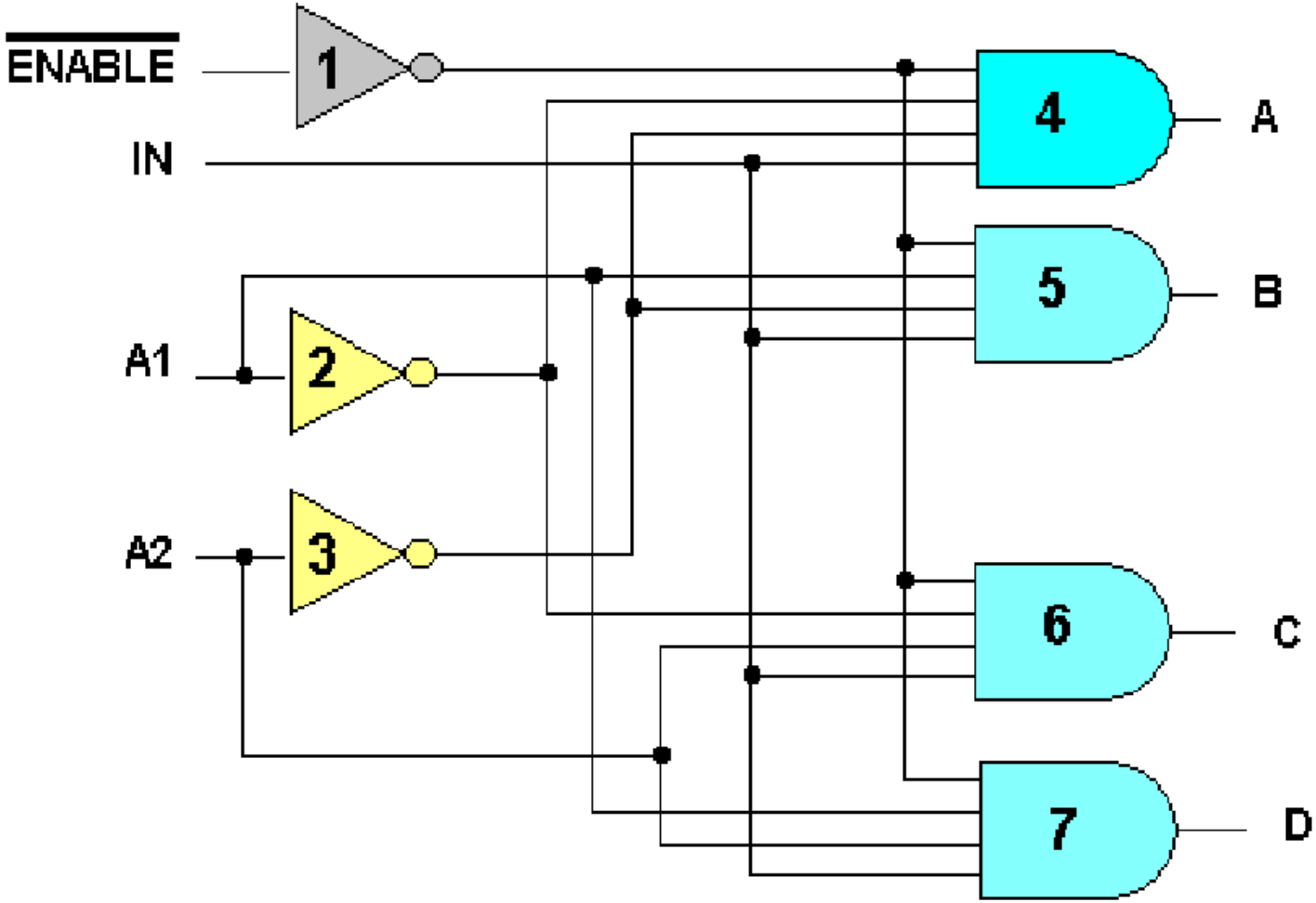
STAIRSTEP RAMP A/D CONVERTER

EL17-S06



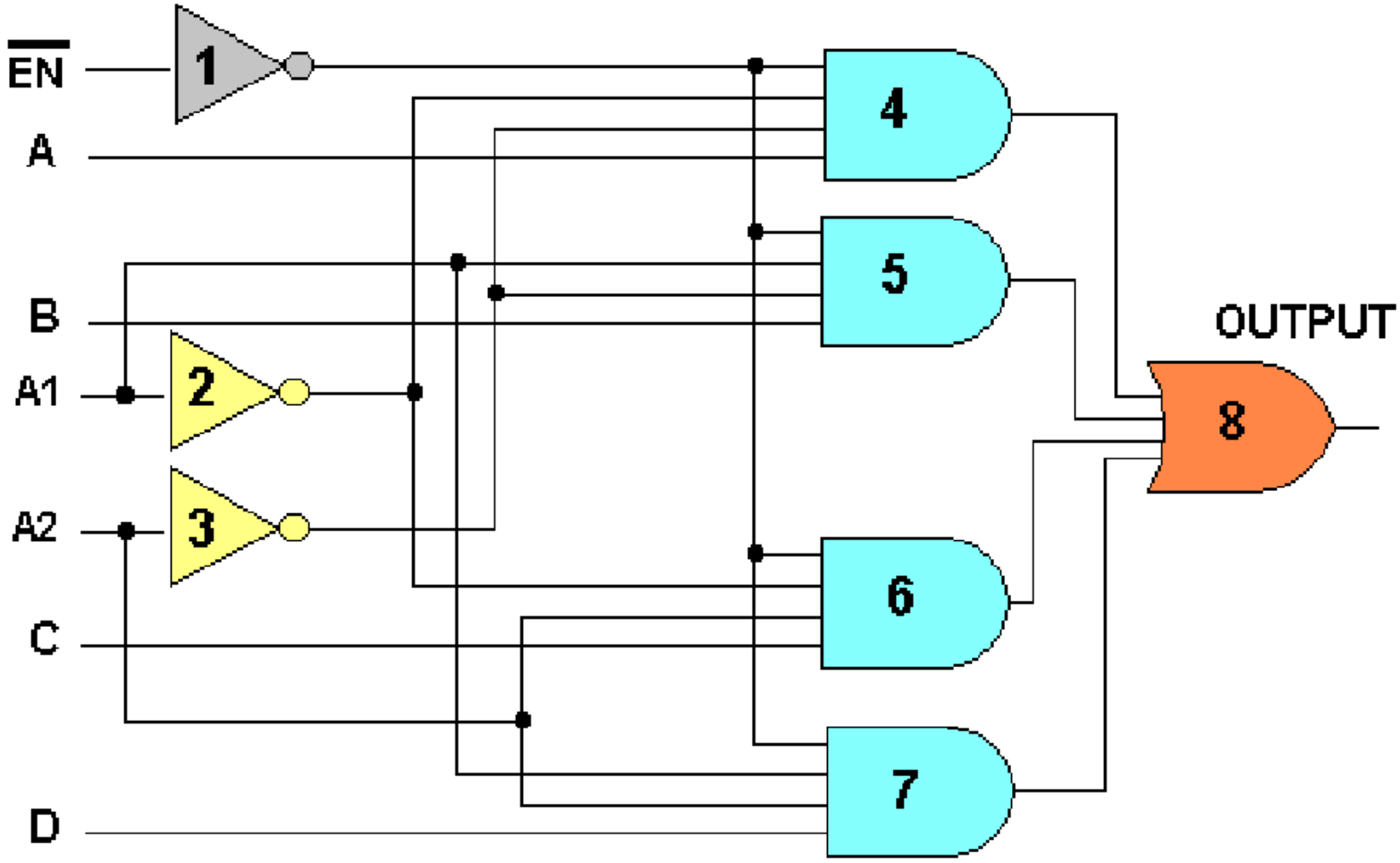
TRACKING A/D CONVERTER CIRCUIT

EL17-S07



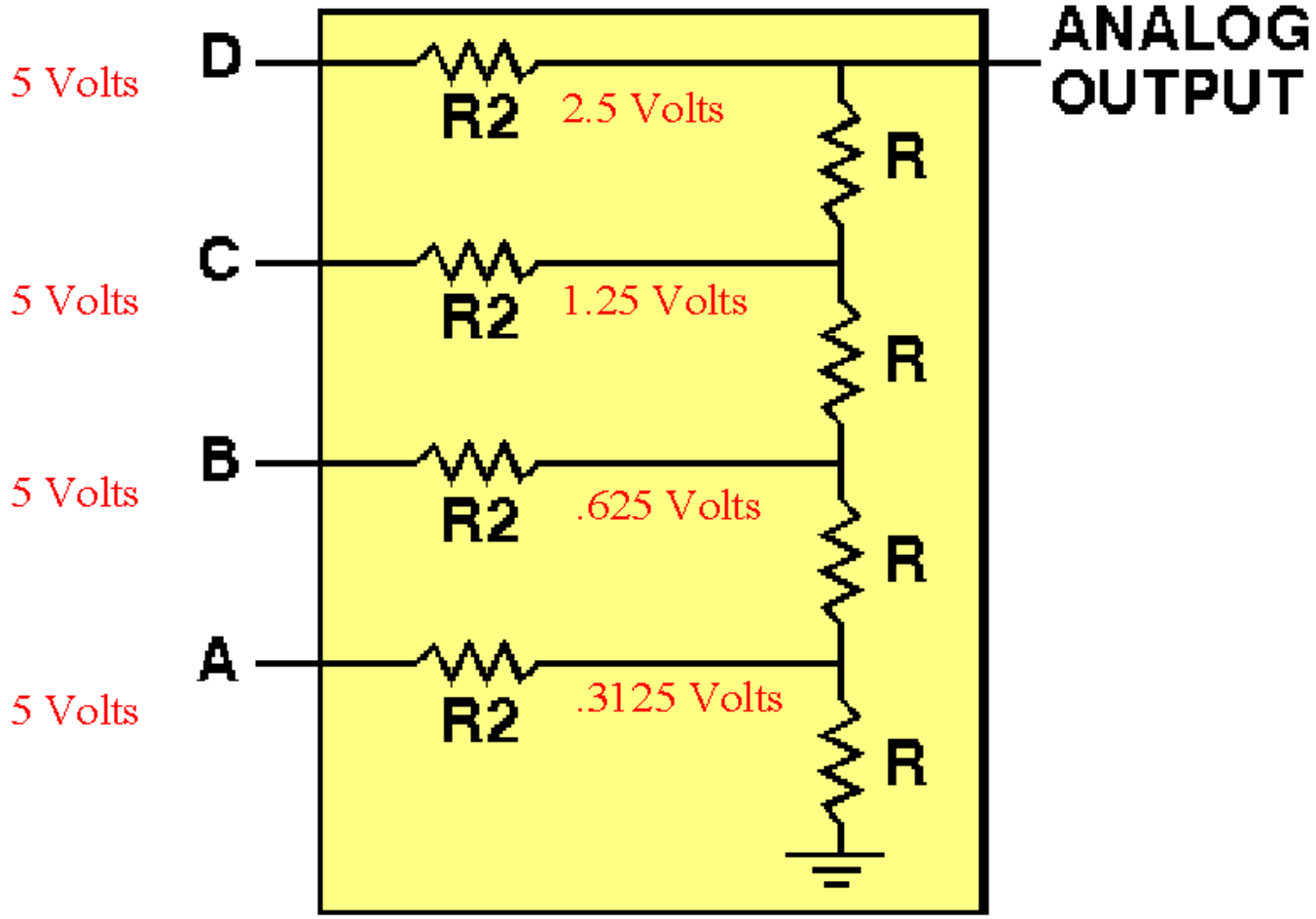
DATA DISTRIBUTOR
(Demultiplexer)

EL17-S09



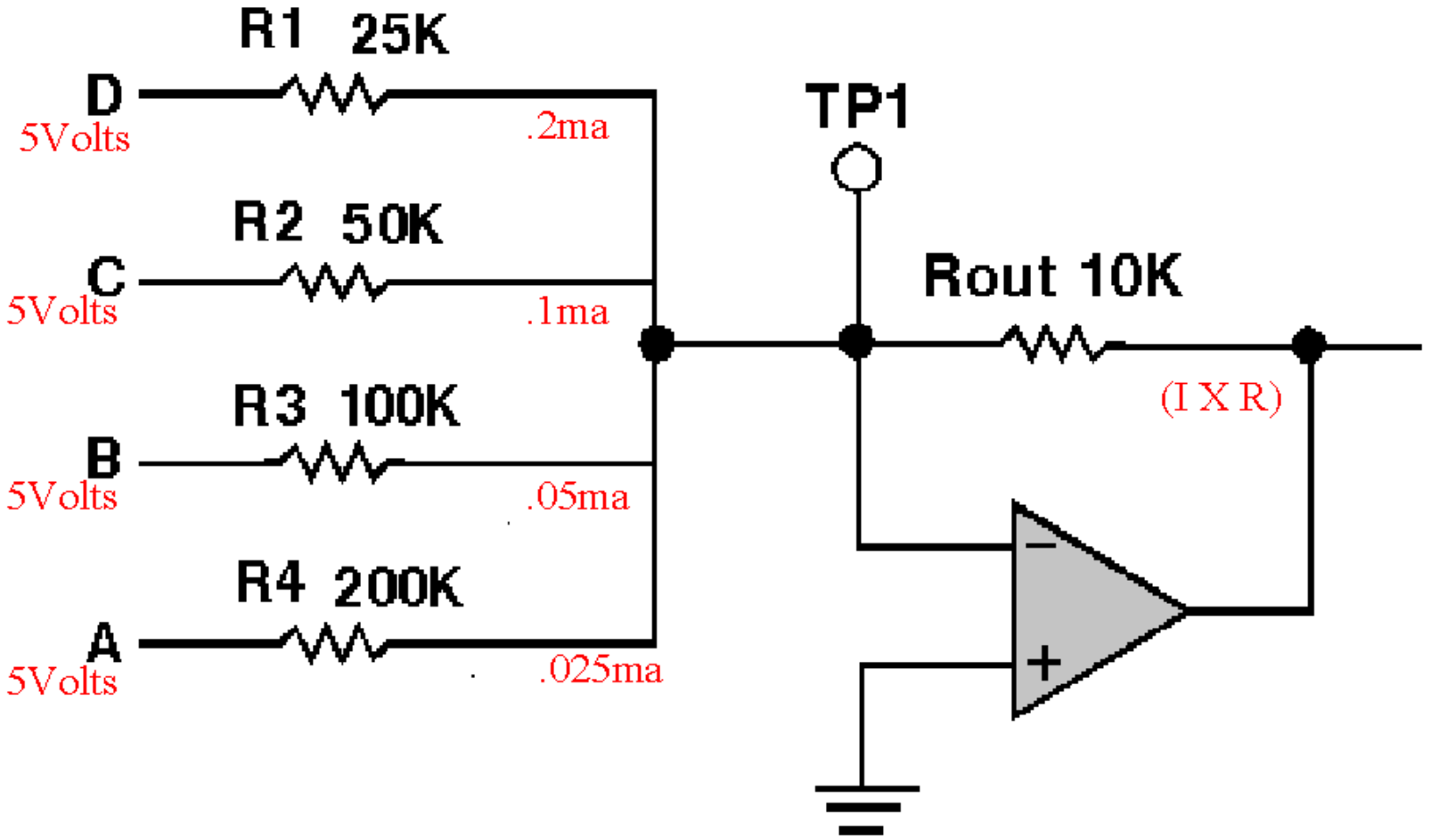
DATA SELECTOR
(Multiplexer)

EL17-S14



4 BIT SCALING D/A CONVERTER

EL17-S18



WEIGHTED D/A CONVERTER

EL17-S19